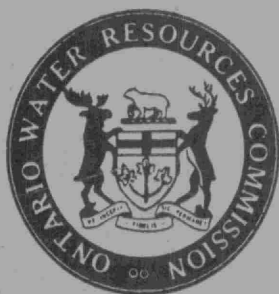


BBNE



SEWAGE TREATMENT MANUAL

— ONTARIO WATER RESOURCES COMMISSION
Division of Plant Operations

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SEWAGE TREATMENT MANUAL

Ontario Water Resources Commission

Prepared by the
Division of Plant Operations

January 1, 1967

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SEWAGE AND ITS COMPONENTS

PHYSICAL CHARACTERISTICS

Temperature

The temperature of the waste has an effect on sedimentation and biological activity. As the temperature increases, the viscosity decreases and the sedimentation improves. Biological activity (the reason sewage decomposes) is a function of temperature and as the temperature increases so the bacterial activity increases. It is, therefore, obvious that as the temperature increases the time required for decomposition will decrease and vice versa.

Odour

The odour of fresh sewage is generally musty and not unpleasant, but sewage beginning to putrify or sewage containing certain types of industrial wastes will have a very objectionable odour due to the production of hydrogen sulphide or other gases.

Turbidity and Colour

Fresh domestic sewage has a greyish colour and a high turbidity. If sewage is of a dark or black colour, it may be an indication of partial decomposition. The occurrence of other colours in sewage is often the result of industrial wastes.

Chemical Characteristics

These are divided into two main groups.

A. Inorganic

This material consists of sand, mud, the dissolved mineral matter in community water supplies and any minerals dissolved from wastes discharged to the sewers. Some of the more common minerals and salts found in water are sulphates, carbonates and chlorides of calcium, magnesium, sodium, potassium and iron.

These are not normally troublesome, but they can affect the treatment process. For example, iron salts may clog air diffusers in an activated sludge plant, or clog the filter media of trickling filters.

B. Organic

This portion of the sewage consists largely of proteins, carbohydrates and fats.

i. Proteins - The products of the decomposition of proteins are nitrogen-producing materials, carbon, hydrogen, nitrogen, oxygen and sometimes phosphorous and sulphur.

The percentage concentration of each of these vary considerably. The main source of nitrogen in sewage is urea or $\text{CO}(\text{NH}_2)_2$, which rapidly decomposes to carbon dioxide and ammonia. On occasion when sulphur is produced in an unstable condition, it may combine with hydrogen to form hydrogen sulphide gas.

ii. Carbohydrates - These are composed of carbon, hydrogen and oxygen in many varying amounts. Typical carbohydrates are sugars and starches. These compounds are normally the first to be broken down by the bacteria with the production of organic acids. It is for this reason that in old sewage the pH may be lower (i.e. higher acidity) than in fresh sewage because of the breakdown of the carbohydrates.

iii. Fats - Fats also contain carbon, hydrogen and oxygen approximately in the concentrations of 76% carbon, 12% hydrogen and 12% oxygen. These fats come from domestic kitchens, tanneries and packing houses. The incidence of fat in a sewage treatment plant creates difficulties because it covers the walls of tanks with grease, and it decomposes producing foul odours and scum. They also tend to coat other organic materials and thus inhibit bacterial action.

Characteristics Commonly Measured

Of all the different types of organic and inorganic material in the sewage received at the plant, the items listed here are of direct interest to the operator - pH, suspended solids, BOD and nitrogen concentration. Solids in sewage are classified under three main headings as total, suspended and dissolved with each of these having two sub-headings - fixed and volatile.

The concentrations of these in sewage will differ to a considerable degree from time to time and from plant to plant. Table I-1 shows the average concentration of solids in a medium strength sewage.

Table I-1
Solids in a Medium Strength Sewage

<u>SOLIDS CLASSIFICATION</u>	<u>CONCENTRATION P. P. M.</u>
Total	500
Volatile	350
Fixed	150
Suspended	300
Volatile	250
Fixed	50
Dissolved	200
Volatile	100
Fixed	100

Biochemical Oxygen Demand - (BOD)

From the point of view of the operator and the engineer, this is the most important characteristic of sewage and is the best indicator of the sewage strength as it is really a measurement of the oxygen required for the biochemical oxidation of the organic material in the sewage within a given time and a specific temperature. The procedure and chemicals used for the determination of BOD are given in "Standard Methods for Water and Sewage", and will be dealt with later.

pH

The pH is a measure of the hydrogen ion concentration of a liquid. This will vary from 0 to 14.0 with 7.0 being the pH of a neutral solution. As the value of pH increases above 7, the liquid becomes more alkaline and with values of pH decreasing below 7 the liquid becomes more acid.

For values of pH below 6.0 and above 9.0, the organisms that stabilize sewage are inhibited. It is therefore necessary that the pH of a digester be maintained around 7.0 if effective digestion is to be achieved.

Nitrogen

Nitrogen appears in organic wastes in various forms depending on the degree of waste stabilization. For sewage there are four kinds of nitrogen, i.e. free ammonia, organic nitrogen, the nitrogen in nitrates and the nitrogen in nitrites. These four constitute the total nitrogen content. As an example, fresh cold sewage will be high in organic nitrogen and low in free ammonia. Conversely, warm stale sewage will be high in free ammonia and low in organic nitrogen.

INFLUENT WORKS

Grit comprises sand, dust, stones, cinders and other heavy inorganic materials. Its removal is necessary to prevent abrasive action on mechanical equipment such as pump impellers and packing glands. Grit collection and removal reduces the hazards of clogged pipes and tank hoppers and usually follows or is a part of the screening unit.

Grit is held in suspension in raw sewage by the velocity of the sewage in the sewer, which is generally about two feet per second. Sanitary sewers are designed to maintain this velocity while combined sewers do permit a slower speed of travel and thus allow some of the grit to settle out in the sewer. This is generally flushed out during wet weather. The velocity of sewage in a grit tank or grit channel is reduced to about 1 foot per second and at this speed the sand and grit will normally settle out while most of the organic material present in the sewage will remain in suspension.

Facilities for Removal

These units are designed in many forms including some which are manually cleaned and others that are mechanically cleaned. These structures may be just two or more shallow, narrow, parallel channels equipped with a velocity control weir or gate. These are normally cleaned by alternatively cutting off the sewage flow, dewatering the channel and permitting any remaining water to drain out of the grit through a drain in a small sump provided at one end of the channel. The grit is then shovelled out into a wheelbarrow and disposed of. In larger plants, the grit is removed by an air lifting device that brings up water and grit from the bottom of a deep, but small tank depositing this mixture into a winding channel or box. The water level is controlled by a gate which permits it to move out slowly leaving the grit behind. The grit is then shovelled into a wheelbarrow and disposed of after the tank has been dewatered. Other installations have large tanks with mechanical scrapers for the collection of the grit to a common point in the tank from where it is pumped into a container for disposal.

The grit which is removed is analyzed for volatile solids concentration, and if this is found to be unusually high, the reason could be that the velocity of flow in the grit tank is too low or that the period of detention of the sewage in this grit tank is too long. It should also be noted that if the velocity of flow of the sewage in the grit tank is too high, there will be a carry over of grit into succeeding sections of the treatment plant with possible damage to mechanical equipment.

All mechanical equipment should be serviced on a daily, weekly or monthly schedule based on the manufacturers' specifications.

Screening

Screening devices are classified broadly as (a) coarse screens or racks; (b) bar screens; and (c) comminuting machines or grinders.

A. Coarse Screens or Racks

These are used for the removal of large objects such as pieces of wood, tree branches, rags or other floating material in the sewage. They are normally placed ahead of regular bar screens or grinding machines to protect them from being damaged by this large material. They are also sometimes located in sewers ahead of a wet well to protect the low lift pumping equipment.

B. Bar Screens

Bar screens are generally next in line in the effluent channel to the coarse screen. In many cases, they constitute the only screening device and are usually placed beside the grinding device or as a by-pass screen to be used during shut down periods of the comminuting or shredding machine. Its function is the same as the coarse screen and it is cleaned by hand rake in small plants and mechanically in larger plants.

C. Comminuting Machines

These machines are available under different trade names such as Barminutor, Comminutor, etc., but all are designed to do the same job, namely to cut up the larger organic solids, rags and other soft materials. This helps in the general break-down and treatment of organic solids and reduces other material such as rags to a size which does not tend to clog pumps.

Management of Screening Facilities

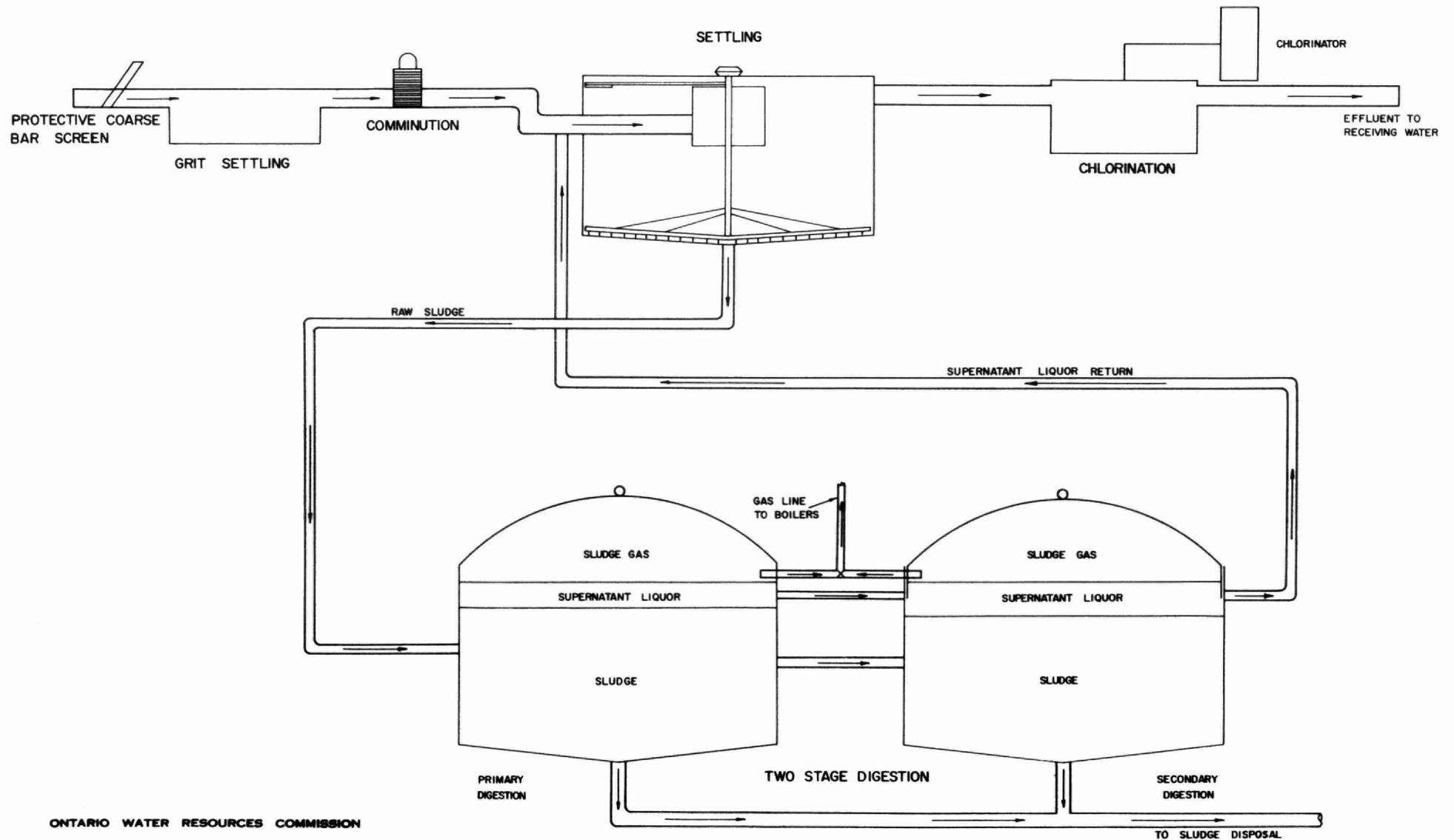
Coarse screens and bar screens should be kept clear of debris as often as necessary to prevent restriction of the sewage flow. In a mechanically cleaned screen or rack, the mechanism should be inspected and lubricated according to the schedule laid down by the manufacturer for that piece of equipment. Comminuting or shredding machines should also be shut down, inspected and lubricated. A short shut down period every few days is recommended with the sewage being by-passed through the bar screen while the stones and other heavy material collected at the bottom of the channel are removed. While this is being done, inspection of the cutting knives and comb is desirable.

Disposal of Screenings

All screenings and other objects collected on the screens should be removed and buried under at least three inches of dirt. In some cases it is necessary to sprinkle chlorine of lime on the screenings if there is any chance of development of an odour. After the screens have been cleaned, either manually or mechanically, the whole area should be washed down with a hose to prevent any residue from remaining and becoming septic. Hosing should also be done in any containers used in the collection or disposal of the screenings.

PRIMARY SEWAGE TREATMENT

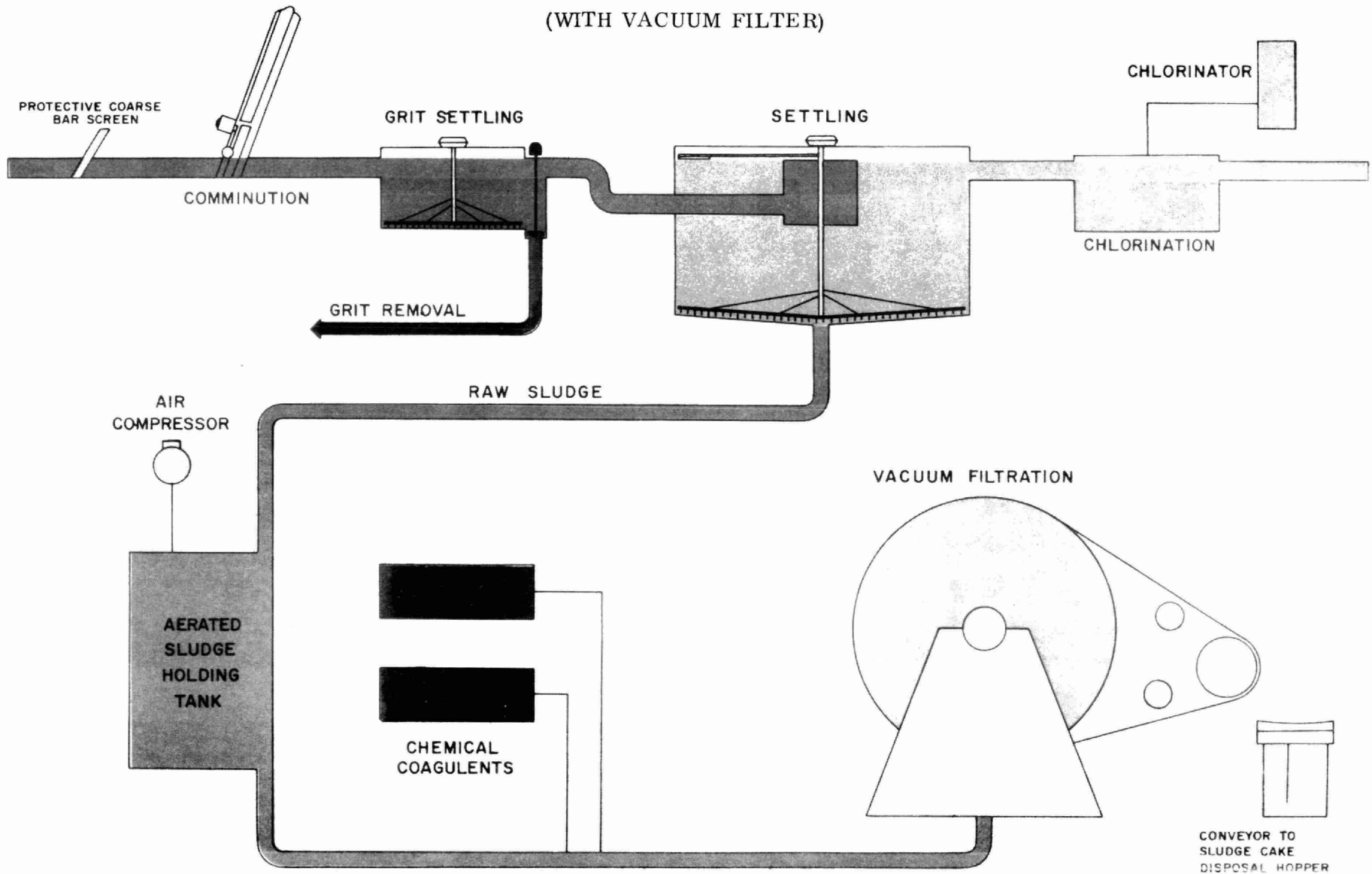
(WITH DIGESTER)



PRIMARY SEWAGE TREATMENT

GREATER SAULT STE. MARIE AREA

(WITH VACUUM FILTER)



PRIMARY SEDIMENTATION

Primary settling tanks remove the heavier suspended material from the sewage prior to its discharge to the receiving stream or to secondary treatment units.

Sewage Characteristics

Sedimentation is effected by the strength of the sewage and the density, shape and size of the particles.

Detention Period

This is the time required for the sewage to flow through the tank at a given rate. The detention period should be sufficiently long to permit removal of settleable solids. Excessive periods of detention do not improve the removal of settleable solids and may actually be harmful by permitting the sewage to become stale.

Inlets and Outlets

Inlets are designed to reduce the velocity of the flow and distribute the sewage evenly across the tank surface. Outlets are designed as ports or weirs with sufficient length or area to reduce the velocity of the clarified sewage leaving the tank. This is necessary to prevent the formation of currents, which would carry the settled material up and over the weirs.

Different Types of Tanks Used

Sedimentation tanks are classified in two groups (a) rectangular and (b) round or square.

A. Rectangular Tanks

Sewage enters the tank at one end and after settling leaves the tank at the other end. A series of scrapers and skimmers move across the surface and along the bottom of the tank on a continuous chain belt, so that the settled sludge is moved into a hopper at the inlet end and the scum collecting on the surface is moved by the skimmers into a scum trough.

B. Round or Square Tanks

Sewage generally enters the tank at the center and flows radially to the outer weir. The settled sludge collecting at the bottom of the tank, which normally flows to the center, is moved into a hopper at this point by rotating scrapers. There are other tank designs in which the sewage enters from the outside weir and leaves by the center of the tank. Sludge collection in these is similar to that previously described. Floating debris is skimmed off into a scum pit and pumped to the sludge conditioning portion of the plant, the digester.

Operation of Primary Tanks

At the startup of a new plant, the first consideration is to check the weir levels. This is done when the tank is full of water at which time the weirs must be raised or lowered so that the flow of water is equal at all points on the overflow. The inlet of a rectangular primary tank has a baffle plate designed to decrease the velocity of flow and to distribute the sewage evenly in the tank.

All weirs and channels must be regularly hosed and scrubbed with a coarse broom to remove accumulations of grease, etc., from the channel walls and floors. This is necessary particularly during the summer months at least three times per week. On a routine inspection, the surface of the water should be checked for signs of floating sludge, water discoloration and gas bubbles, as these are signs of mechanical break-down, septic conditions in the raw sewage or the inflow of supernatant liquor from the digester. The primary tanks should be checked several times during each shift and the mechanical check and servicing should be done according to the instructions on the lubrication card.

Sludge Collection

In rectangular tanks the collectors are often run for only an hour before sludge pumping is commenced. Many of these units have a timing device on the collectors, as well as on the sludge pumps and valves, so that this additional hour of sludge collection can be accurately controlled. In round or square tanks, generally referred to as clarifiers, the collecting mechanism is run continually to prevent a buildup of sludge on the bottom of the

tank too heavy for the sludge collectors to move.

Raw Sludge Characteristics

The condition of the raw sludge is dependent largely upon the strength and freshness of the sewage, the detention time of the sedimentation tank and the frequency of sludge removal.

Sludge Pumping

The concentration of solids in sludge pumped from the primary sedimentation tanks varies from plant to plant, but will be in the range of three to five percent. Pumping should be for short durations at frequent intervals rather than long duration at infrequent intervals. Sludge can be pumped only as fast as it can be moved into the primary tank sump by the collectors, or as fast as it will settle to the intake level of the pump in the hopper. If an attempt is made to pump sludge too fast, or for too long a period, a good concentration of sludge will be removed in the first few minutes, but then the lighter settled sewage will be drawn into the pump suction and be transferred to the digester. Excess liquid pumped into the digester occupies valuable capacity, causes a waste of fuel and power and causes an excessive quantity of supernatant liquor to be returned to the plant. The volume of sludge that should be removed from the primary settling tanks can be estimated by measuring the suspended solids in the influent and effluent.

The raw sludge pump should be inspected for operational performance after each period of service and should be hosed down as soon as pumping has been completed.

Operational Problems

Symptom A: Floating sludge or pads. This is caused by the decomposition of sludge in the tank and the gas produced raises this sludge to the surface.

Action to be Taken

Apply the hose to the surface of the tank so that the water under pressure breaks up the sludge formation permitting the solids to resettle. To avoid a recurrence of this condition, sludge should be removed more frequently, but if sludge continues to float to the surface, it is necessary to check the scraper mechanism for broken or warped units.

Using a long pole fitted with a scraper, the sides of the sludge hopper should be squeegeed to loosen the accumulation of sludge sticking to the sides and permitting it to settle to the bottom of the hopper.

Symptom B: Contents black and odourous. This is usually caused by the raw sewage being septic on entering the plant, or by returning a very strong supernatant liquor to the primary sedimentation tank inlet. One explanation for receiving septic sewage at the plant could be that the velocity of flow in the sewers is too low permitting solids to settle out and putrefy. Also contributing to this problem, is the possibility of septic tank effluent being permitted into the sanitary sewers.

Action to Be Taken

If septic sewage is being received at the plant, the only thing an operator can do is to chlorinate the sewage ahead of the primary tank and this is only possible where equipment is available. If the return of strong supernatant has been the cause of septicity, it is necessary to reduce the rate of withdrawal of the supernatant from the digester or to make withdrawals during the night hours when the sewage flow is low. Supernatant should be withdrawn at different levels and, if the supernatant withdrawn at all levels appears to be very heavy, then a check should be made in the digester.

Symptom C: Very heavy sludge, which is difficult to remove from the hopper. This is caused by a high concentration of sand and grit in the sewage flowing into the primary sedimentation tank, or else by a low velocity in the withdrawal lines of the raw sludge pump.

Action to Be Taken

First make a check on the grit removal equipment and if defective, change it where possible. Squeegee the slopes of the hoppers and pump sludge at the same time, being careful not to push too much material down to the bottom of the hopper at one time. Any sludge compacted at the bottom of the hopper, can be loosened by fastening the hose to a long pole, lowering this in the tank to the sludge level and applying water under pressure at close range. If the air line and the water hose are of the same diameter, and the water hose is long enough, it is handy to fasten this to the air line and blow out the compressed sludge with air.

AERATION TANKS

The aeration tank is the heart of the activated sludge process where oxygen is introduced into the mixed liquor to satisfy the requirements of the activated sludge organisms and to keep them dispersed in the aerated liquor. The tank capacity must be sufficient to provide enough detention time for the accomplishment of the required purification. Aeration tanks vary in size according to the rate of flow and many other treatment requirements.

Oxygen Supply

By virtue of their design, aeration tanks limit the quantity of dissolved oxygen that can be introduced into solution at a given time. For every type of tank, there are two sources of oxygen that control the rate of solution:

- A) Oxygen absorbed from the diffused air bubbles introduced under pressure and entrained in the aerated liquor.
- B) Oxygen absorbed from the air above the tank surface during the agitation of the mixed liquor.

The solubility of oxygen in the mixed liquor from the air bubbles introduced into the liquid depends largely on the time of contact between the bubble and the liquid and the turbulence in the liquid. Because this rate of solubility is normally slow, it can be increased by creating more turbulent conditions in a tank.

The rate of solubility of oxygen from the air above the tank surface is proportional to the surface film of liquid which is normally saturated with oxygen, with the main body of the liquid.

Types of Aeration Tanks

There are two main types in common use (a) diffused air; (b) mechanical.

a. The diffused air method uses the principle of introducing compressed air into the tank at the bottom through a number of down pipes on each of which there is a header equipped with various types of air diffusers, such as Sparjers, wrapped tubes and sometimes just perforated pipes.

The air from these outlets surges upward lifting the water with it creating an upward flow. This with the design of the tank causes the water to rotate in a spiral motion as it passes through the tank.

b. Mechanical aeration. This type employs several kinds of agitators, One is a draft tube and propeller with the motor mounted directly over the unit. This type draws the mixed liquor up through the tube which spreads the liquid out over the tank surface. The unit can be on a timer and operated for different lengths of time as desired.

Another type uses just one motor and the agitators are driven by a line shaft, Up to 3 units are used on one line shaft. This unit has paddles on a circular frame which revolves. This picks up the liquid and throws it out over the surface. The control of this unit is by a movable weir that can be raised and lowered to increase or decrease the amount of water that is thrown. Also several different sizes of gears are available for shaft speed control.

The retention time varies with the type of aerator used and the degree of treatment required. Normally a period of 6 hours is employed.

FINAL SETTLING TANKS OR CLARIFIERS

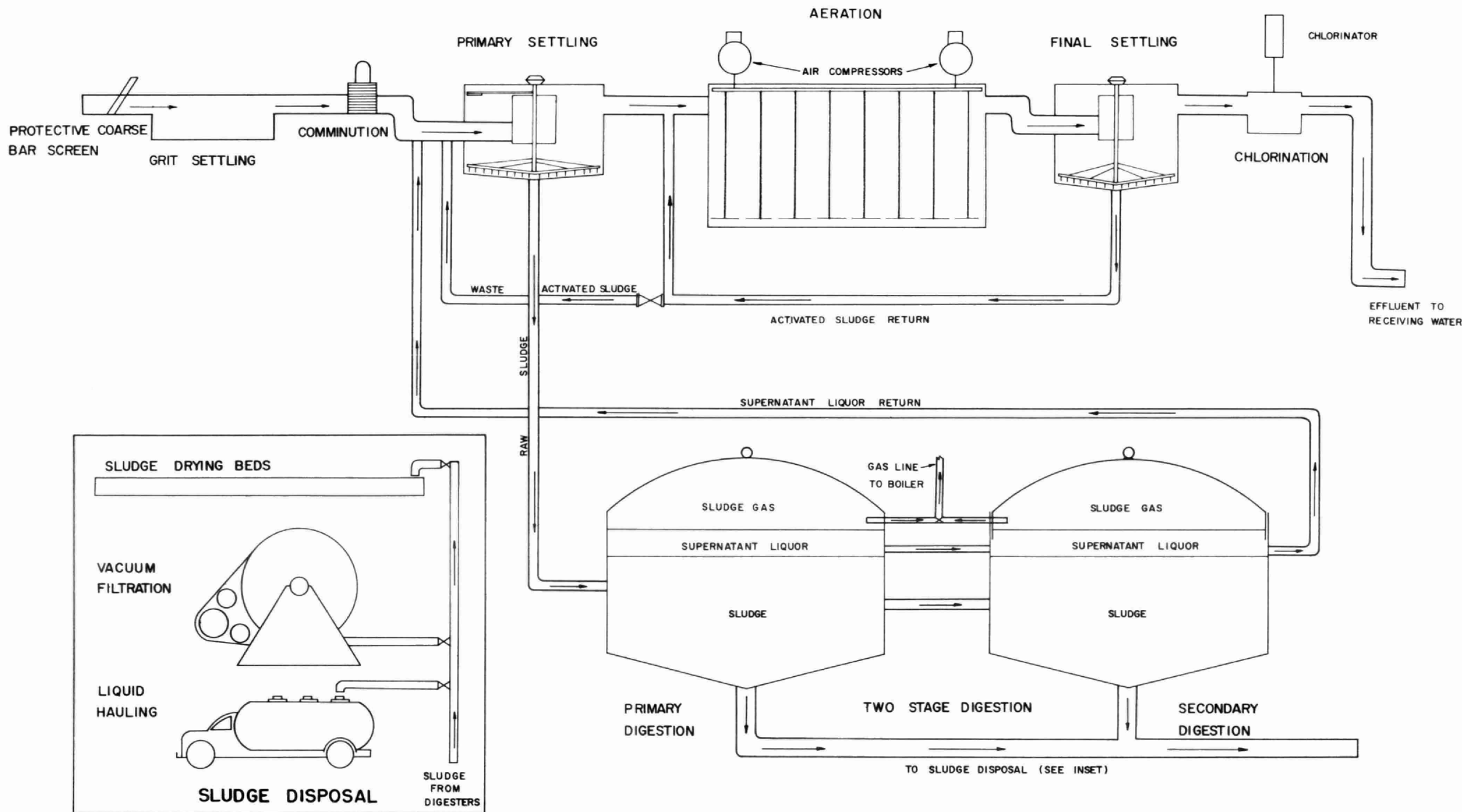
The purpose of the final tank is to bring about the separation of the activated sludge from the treated sewage. The mixture enters these tanks and is deflected to the bottom by baffle plates.

The sludge settles rapidly and is moved to withdrawal points where it is removed continually by return sludge pumps. The clear water or effluent flows over the weirs and on to the chlorine contact chamber and then to the receiving stream.

Detention time in the final settling tanks is normally about two hours.

SEWAGE TREATMENT

BY THE ACTIVATED SLUDGE PROCESS



Sludge Removal

It is good practice to "sound" tanks for sludge blanket depth and location. This is done by using a 2" x 2" pole of sufficient length with a bottle fixed to the pole with large hose clamps at the bottom of the pole. This bottle should have a wide neck and have a capacity of approximately half a pint or 250 ml. It is fitted with a cork and a fine flexible wire is attached to the cork and is led to the other end of the pole. This sound pole is used by introducing it with the bottle corked into the final or any other tank. With the pole end resting on the floor of the tank, the wire is pulled thus removing the cork from the bottle and introducing to the bottle a sample of the material at that depth.

The pole should be marked in feet. The sludge accumulation to be maintained at the bottom of the tank must be determined after the plant has been in operation for some time.

ACTIVATED SLUDGE PROCESS

This process is utilized to convert non-settleable substances in finally divided colloidal, and dissolved forms into settleable sludge and to remove this sludge thereby providing a high degree of treatment. This first part, that is the conversion of colloidal and dissolved material into settleable sludge, is accomplished in aeration tanks and the removal of this sludge is accomplished in the final tanks.

The activated sludge process depends on groups of micro-organisms, primarily bacteria and protozoa, feeding, living and multiplying on the solids in sewage, reducing the solids to a more simple form and thus affecting a purification process.

These organisms are maintained in an aerobic environment by the introduction of air into a mixture of activated sludge and the effluent from the primary sedimentation tanks. This mixture called mixed liquor is agitated by the action of the air and is retained in the aeration tank for a fixed period of time. The mixture is then passed into the final sedimentation tanks where the activated sludge is separated from the treated sewage by settling to the bottom of the tank. The efficiency of the settling is determined by the weight and density of the sludge developed.

This sludge that settles out is then pumped back to the entrance of the aeration tank where it is mixed with more of the effluent coming in from the primary sedimentation tanks. It is referred to as return activated sludge.

The rate that the settled activated sludge in the final tanks is pumped back to the aeration tanks can be set at 25% of the total incoming sewage flow entering the plant for 24 hours.

This 25% figure is a basic one. The actual % of return sludge at any plant must be calculated on several factors besides the daily flow, e. g. , the strength of the sewage measured by the BOD, the freshness of the sewage, industrial waste it may contain and other operating as well as design features pertaining to any given plant.

Since the activated sludge is constantly increasing in quantity as it removes organic solids from the sewage, and as the micro-organisms continually grow and multiply, it is necessary to remove the excess quantity from the system. The sludge so removed is called "waste activated sludge" and is "wasted" to the entrance of the primary sedimentation tank.

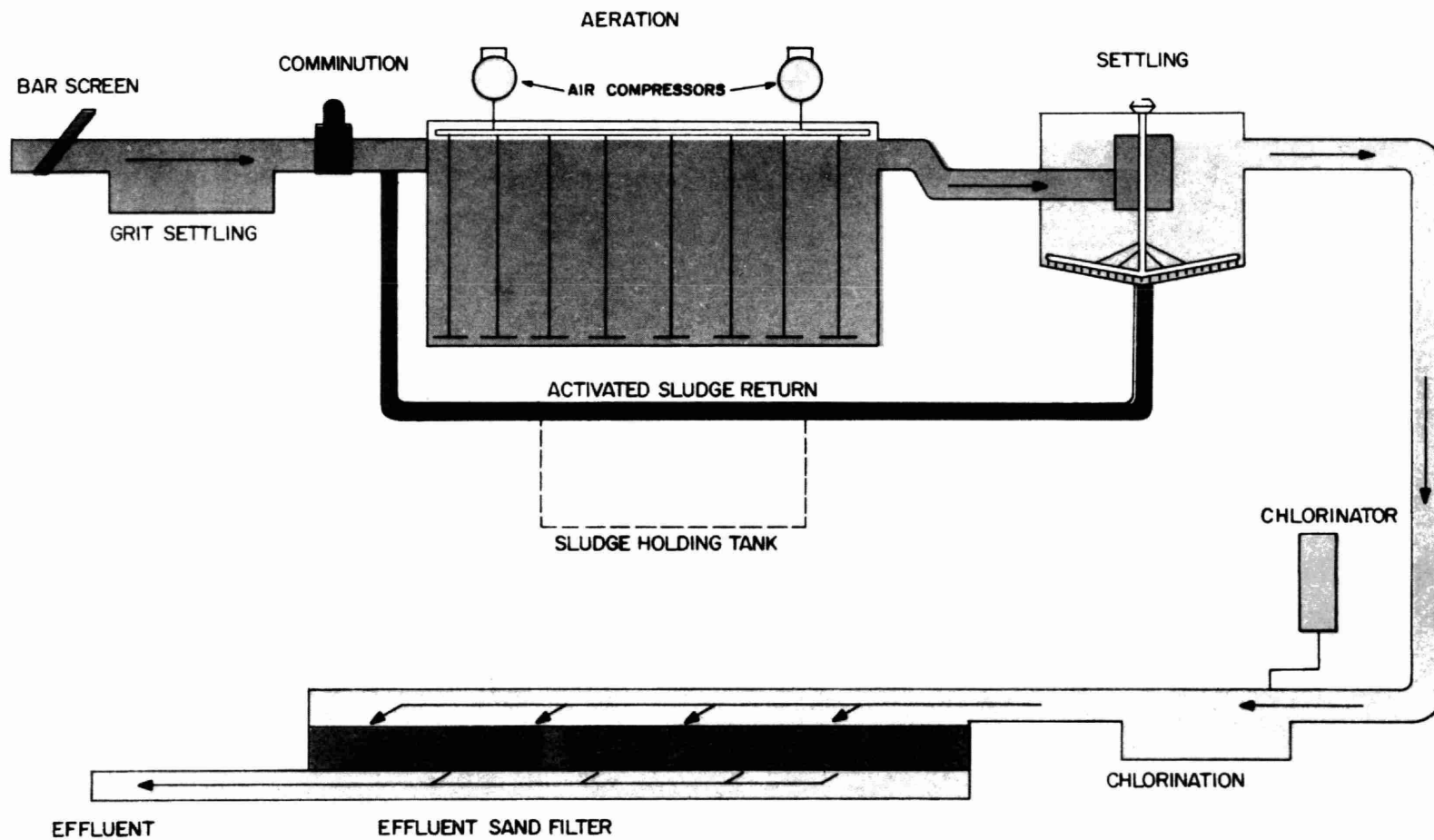
It will often be found that it is not necessary to waste sludge continually to the primary tanks as certain characteristics of the sewage, such as a pH below 6 or above 9, that is high acidity or high alkalinity respectively, the presence of toxic materials, the occurrence of over-oxidation of the mixed liquor in the aeration tanks during low flows, and other balancing effects provided by nature will tend to maintain the bacterial growth at a fairly steady rate. Occasionally some combination of these conditions reduces the bacterial growth to an undesirably low level.

Essentially this process is a simple one, which has three basic requirements:

1. The activated sludge should contain sufficient numbers of purifying micro-organisms.
2. Dissolved oxygen should be present in a sufficient and almost uniform concentration throughout the aeration tanks.

SEWAGE TREATMENT

BY THE
TOTAL OXIDATION PROCESS
(MODIFIED ACTIVATED SLUDGE)



3. The activated sludge should separate readily from the treated sewage in the final tank.

In practice, the process is not quite so simple since there are a number of variable factors to be dealt with. The life cycle and rate of growth of the purifying micro-organisms can vary considerably, thus imparting rapidly changing conditions. If your plant handles industrial wastes as well as domestic sewage, the material received at the plant in the sewage will at times upset the whole process. The spring thaw runoff and any extra heavy rains will tend to wash out the process.

TOTAL OXIDATION TREATMENT (Modified Activated Sludge)

The total oxidation process is a method of complete biological treatment that produces a high quality effluent.

This process is identical to the activated sludge process in its biological application, but has no primary settling and all the solids contained in the waste water are oxidized through an extended aeration period.

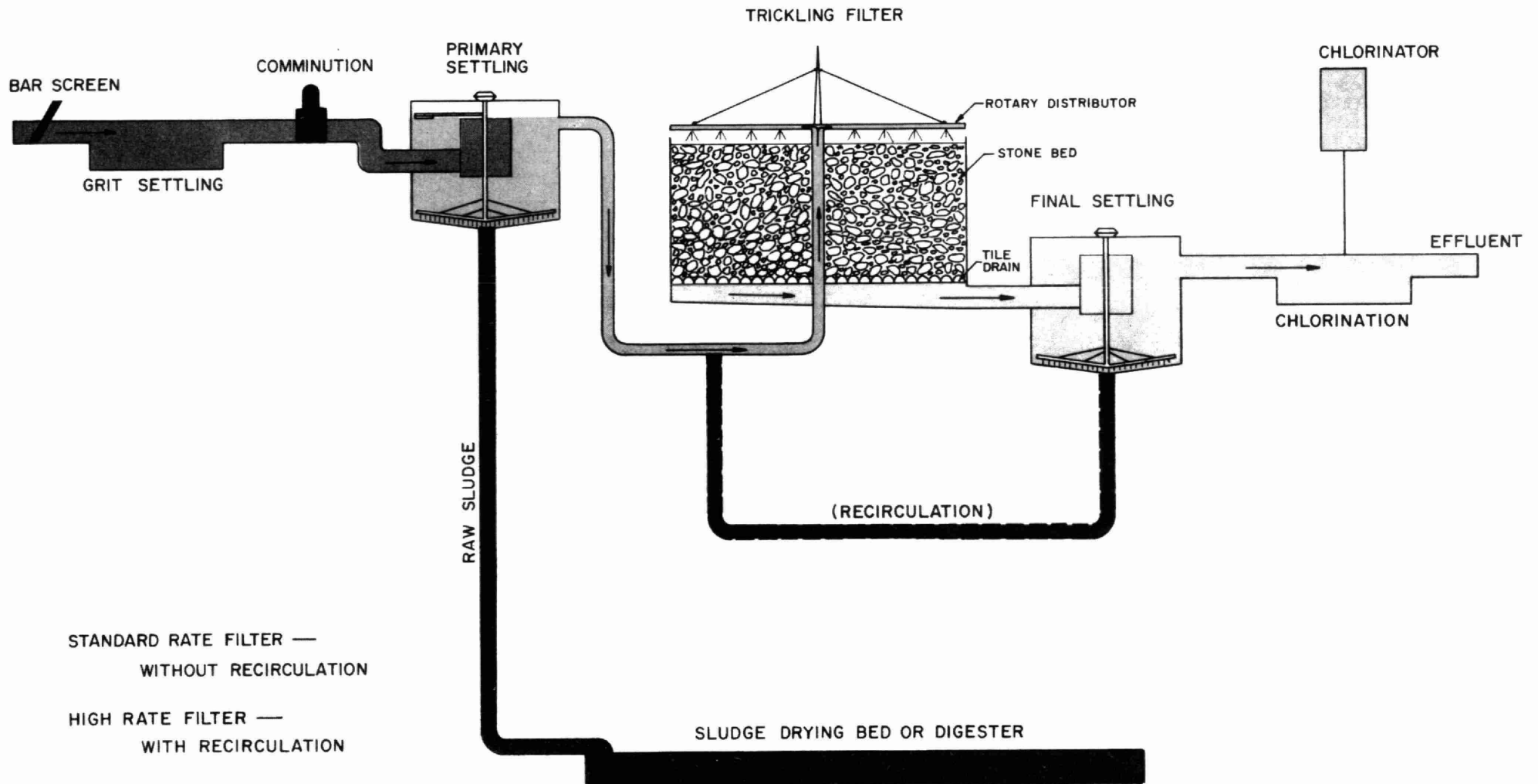
Biological communities of micro-organisms are developed and maintained in aeration tanks where they are supplied with a plentiful supply of oxygen. The air supply can be provided by compressed air, which is piped directly into the tank, or by means of a mechanical agitator, which revolves and disperses the surface area to allow a greater absorption of atmospheric oxygen by the tank's contents. Besides providing ideal conditions for the micro-organisms, the air, or agitation, also produces a roll in the tank and prevents settling of the solids.

As the organic impurities are assimilated (oxidized) by the micro-organisms, the resulting sludge formation is light and flocculent and can readily be settled. This sludge is the vehicle upon which the bacteria grow and provide the means of maintaining the process.

Final settling tanks remove and reclaim this sludge floc. As the effluent from the aeration tanks passes through these settling tanks, the settled sludge is removed and re-

SEWAGE TREATMENT

BY THE TRICKLING FILTER PROCESS



turned to the aeration section by means of a pump or pumps, mixing with the incoming sewage. This sludge is referred to as activated sludge because of the biological communities growing in and upon it.

The small amount of inert and oxidized matter remaining after a period of time is periodically removed to a holding tank or sludge drying bed for final disposal.

To summarize: Air is supplied to the micro-organisms, which in turn oxidize the organic materials in the waste water. The amount of solids removed ranges from 90 to 95 percent.

TRICKLING FILTER TREATMENT

Standard Rate Trickling Filter

The trickling filter process removes the finely divided, suspended and dissolved materials remaining in the waste water following primary treatment, which removes the heavier settleable solids.

The filter is constructed of a bed of crushed rock which provides a large surface area for the development and growth of colonies of micro-organisms.

Aerobic nitrifying bacteria build up on the crushed rock and, as the waste water is fed through, the organisms oxidize the organic materials contained in the water. The oxygen required by the organisms is supplied from the atmosphere, passing down through the bed.

The waste water is discharged on the media by a rotary distributor which places an even flow over the entire surface area.

The underdrain system is a specially constructed tile which supports the stone and carries off the effluent. As the filter builds up with the oxidized material, it periodically falls away from the filter media. A final settling tank provides sedimentation to the effluent from the filter and collects these oxidized particles.

High Rate Trickling Filter:

Recirculation, as shown on the diagram, on page , provides additional biological treatment and is especially useful in treating certain types of industrial wastes. The methods and points of recirculation vary with design and equipment, but the filter is constructed the same as the Standard Rate Filter.

To summarize: The aerobic micro-organisms, supplied with oxygen, oxidize the organic matter and produce a rapid settling. This form of treatment produces a high degree of purification. The amount of solids removed ranges from 90 to 95 percent.

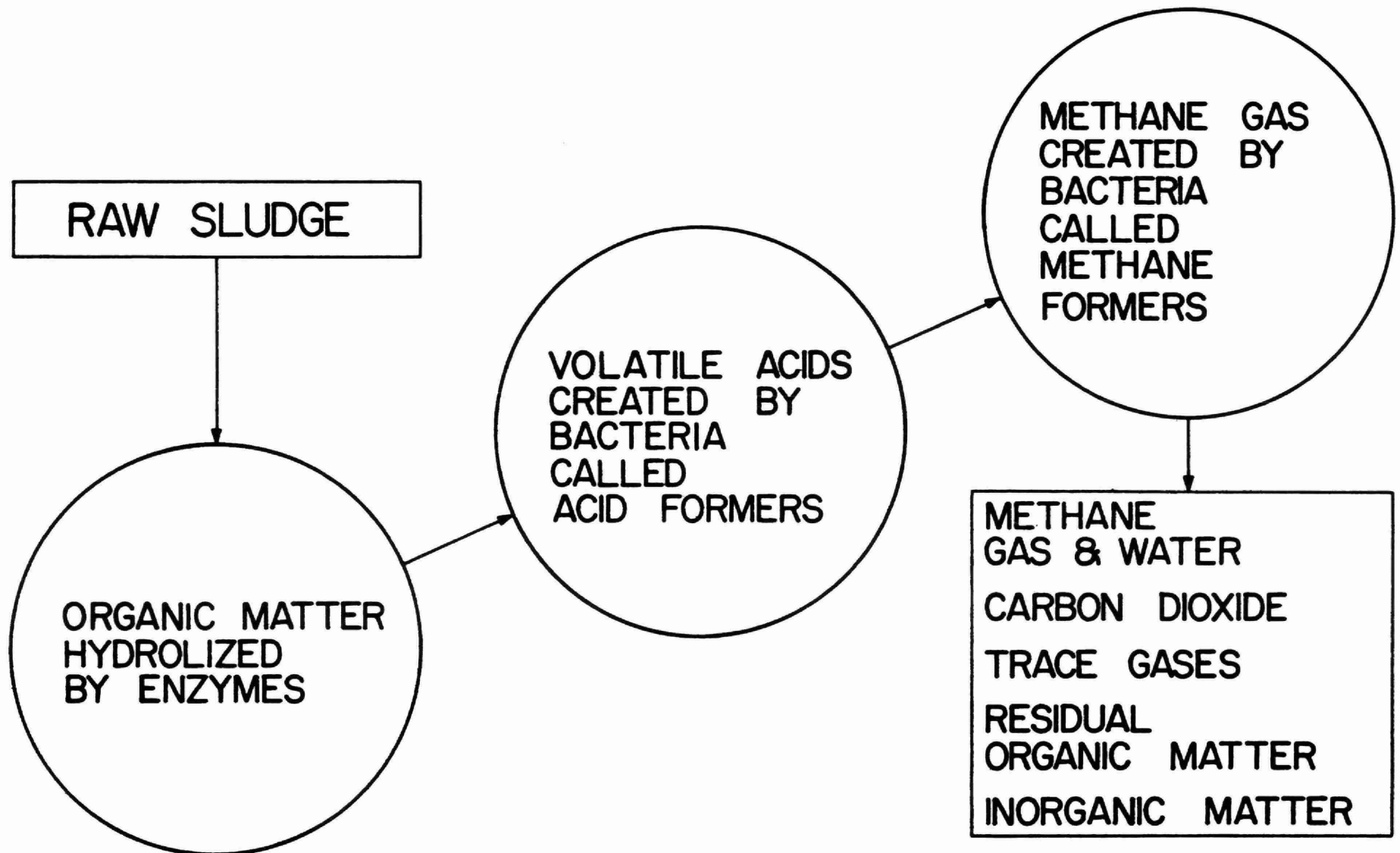
PURIFICATION PROCESS IN STABILIZATION LAGOONS

In order to allow a better understanding of the manner in which organic material contained in waste water is oxidized or converted to stable compounds in a Waste Stabilization Lagoon, a brief description of the class of micro-organisms involved is included. The descriptions are brief, but the main points explained are pertinent to the purification of waste water.

BACTERIA

Bacteria are microscopic organisms of various shapes--spherical, elliptical, cylindrical, filamentoid, etc.--constituting the most elemental forms of life. They are very widely diffused in nature, and multiply with great rapidity. Their nourishment consists of albuminous substances, which they convert into complex chemical compounds. The study of the chemistry of bacteria has shown that many of them do not grow upon living matter, but will flourish upon decomposing and putrefying substances, such as the organic waste materials found in sewage. Bacteria also convert inert matter into available plant food, changing organic nitrogenous substances into soluble nitrates.

BASIC ANAEROBIC ALKALINE DIGESTION PROCESS



DIGESTION

— OPTIMUM OPERATING STATE

ANAEROBIC

PROTEIN

PEPTONES

AMINO ACID

FATS

GLYCEROL

CARBOHYDRATES

GLUCOSE

MICROBIAL ABSORPTION

AMINO ACID

GLYCEROL

GLUCOSE

VOLATILE ACIDS
HYDROGEN SULPHIDE

VOLATILE ACIDS
ALCOHOL

VOLATILE ACIDS
300-500 PPM

METHANE

CARBON DIOXIDE

TEMPERATURE
90° - 95°
PH 7

Physiology of the Bacteria: Nutrition -

Most of the food utilized by bacteria is in the form of insoluble solids or colloidal solutions. Bacteria possess no mechanisms for ingesting such material. Most animals are capable of taking into their digestive tracts solids, particulate foods, and transforming them into a soluble condition through the process of digestion. In the case of bacteria, the digestive processes concerned in transforming insoluble foods into a soluble condition must take place outside the organisms' body.

The chemical changes involved are the same whether they take place within or without the body of the organism. The active agencies in digestive juices are "enzymes", that is, organic protein catalysts synthesized only by living cells.

THEORY AND DESCRIPTION OF SLUDGE DIGESTION

Sludge from the primary tanks that is both raw and waste activated sludge is pumped to the digester. The duties of this tank can be listed, as:

1. To decompose the organic matter to a relatively stable or inert inorganic material.
2. To reduce the volume of material to be handled by the removal of some of the liquid portion.
3. To utilize the gas by-product of the process for heating, to reduce the overall cost of operation.

Sludge digestion is carried out in the absence of free oxygen by anaerobic organisms. It is therefore called controlled anaerobic decomposition. The solid material in raw, domestic sludge is generally composed of 70% organic and 30% inorganic or mineral. Water in the raw sludge is called "bound water", which will not separate from the sludge solids, but in the process of digestion the living organisms break down the complex structure of these solids releasing this bound water and obtaining oxygen and food for their growth.

The activity in a digestion tank can be described as a three-stage process.

1. The micro-organisms attack the soluble or dissolved solids, such as sugars, and produce organic acids, sometimes in concentrations up to 2,000 ppm. Hydrogen sulphide carbonates and carbon dioxide are also formed. The hydrogen sulphide gas gives off an extremely unpleasant odour and the colour of the sludge will be a dirty grey. The pH may be lowered to from 6.8 to 5.1 or less. This lowering of pH is called acid fermentation and proceeds rapidly.

2. The second stage is an acid regression or reduction stage brought about by organisms which thrive in an acidic environment. Organic acids and nitrogenous compounds are attacked and liquefied at a much slower rate. The pH then increases through a range of about 5.1 to 6.8 and the sludge colour changes from grey to a yellowish brown with a tendency to foam. In this stage, gas production decreases but those gases that are produced are carbon dioxide with some methane.

3. The third stage is a period of intensive digestion, stabilization and gasification. The remaining and more resistant nitrogenous materials such as proteins are broken down and the volatile acids are reduced. The pH is stabilized within the range, of 6.8 to 7.4 with an associated high methane gas production. The solid materials left, settle to the bottom of the digester. They are still slightly active, being referred to as ash but can be pumped to drying beds or elsewhere with little or no odour.

Single Stage Digesters

In a single stage digester, all of the above described stages take place at the same time. As fresh sludge is added, supernatant water is removed and the whole process operates like a production line.

Although all these stages proceed simultaneously, the acids produced during the first stage are neutralized during the second and third stages when the pH is found to be 6.8 to 7.4.

It is generally only possible to recognize the first two stages of digestion at the start-up of the digester, since after the tank contents have reached an alkaline operating condition, the acids stages are not apparent unless the digester is upset by overloading, a drop in temperature or the withdrawal of too much digested sludge.

Limitations of Single Stage Digesters

The contents of the digester are naturally mixed to some degree by the gases rising to the top, but this is not sufficient to mix the raw sludge being fed into the digester or to keep the formation of surface scum to a minimum.

Some method of mixing is therefore necessary and this can be done either by mechanical means or by gas recirculation.

This mixing of the contents however interferes with the separation of solids from liquid, causing a high solids content in the supernatant. Nevertheless, a study of the pumping requirements, that is time of pumping, amount and frequency, will normally show the best time for supernatant removal.

Two Stage Digestion

This method uses two digesters connected in series and the first or primary digester is the same as in the single stage method. It is fitted with some method of mixing, but in two stage digestion the mixers may be operated at any schedule. The more mixing that is provided, the more homogeneous are the contents of the tank, and, therefore, gas production is at its maximum.

The second digester acts as a receiving tank for the supernatant overflow and digested sludge. The sludge can be transferred either by pump or overflow pipe and thus this material can remain in a quiescent condition. Sludge may be removed at any time and in any amount. The supernatant liquor will normally be quite clear and free of suspended solids. It should be noted that two stage digesters require somewhat less careful control in their operation than single stage digesters, since

the last basic step in the digestion process--settling of the sludge-- is done in the second or holding digester.

Food Supply

The organisms in a digester are most efficient when their food is supplied in small quantities at frequent intervals. If too much sludge is added to the digester, the first stage may become predominant and the environment for the organisms of the second stage becomes unsuitable, often to the extent that their activity is reduced or even stopped. This results in incomplete digestion.

Digester Feed Supply

The sludge pumped into the digester each day must be recorded so that the operator will know how much total material he is putting into the digester. This can be done by the simple process of converting his daily liquid pumpings into lbs. per day dry solids.

Example:

Raw Sludge pump capacity = 60 gals. per min.

pumps two primary sumps per pumping for 5 min. each

pumps twice per day = 20 min. of pumping per day

20 min. pumping at 60 gals. per min. = $20 \times 60 = 1200$ gals. per day.

1 gal. weighs 10 lbs..

Assuming the sludge being pumped contains 3% of solids, this then is 1200 gals. $\times 10 \frac{\text{lbs.}}{\text{gal.}} \times .03\% = 360$ lbs. of solids pumped to the digester each day. Of this 360 lbs., about 75% or 270 lbs. is volatile or organic material. The other 25% is inorganic (sand, etc.)

During the process of digestion, assuming the maximum rate of breakdown of the volatile or organic material is 50% of the daily input of sludge, this leaves 50% of 270 lbs. = 135 lbs. plus the 25% or 90 lbs. of inorganic material = $135 + 90 = 245$ lbs. of material per day collecting in the bottom of the digester.

The operator knowing the size and capacity of his digester should be able to keep track of his storage space in the tank and know how often he should withdraw sludge.

Time & Temperature

Sludge digestion can proceed in a temperature range 65°F to 130°F, but the time required for complete digestion varies greatly with the temperature. The types and amount of gases produced will also vary with the temperature of digestion.

At the lower end of this temperature range, digestion is carried out by one set of micro-organisms while, at the other end of this temperature range, a different kind of bacterial strain is predominant. The time required for complete digestion is governed also by the concentration of volatile solids in the sludge.

The optimum heat range, therefore, and careful mixing are required to break down and reduce the volatile matter to a good digested sludge with the maximum production of gas. This range is generally accepted to be between 90°F and 95°F.

Digester Covers

These are normally listed as two types, (a) fixed and (b) floating. Fixed roofs are normally of a dome shape with one or more mixing machines fitted on the top. Others with gas recirculation as the method of mixing in the primary or single stage digesters have no mixers on them. Some secondary digesters use flat roofs. On a fixed roof the supernatant overflow is sometimes controlled by piping from a tank into a concrete box located on the roof. From this box, it travels through another pipe to the secondary digester, if there is one, or back to the plant. Control of this supernatant drawoff is by removable rings on the pipe, which is necessary to maintain the liquid level in the digester. Supernatant can be drawn off at various levels and it is recommended that the liquid be removed at the lowest level where clear water is evident. A floating cover can sit directly on the liquid and ride up and down with the liquid level in the tank. Another type is designed to hold gas, and the roof floats on a cushion of digester gas above the liquid level. The build-up of pressure in the tank keeps the roof above the liquid and thereby provides a gas reserve. This

kind of roof, too, will vary in elevation depending upon the liquid level and the increased build-up of gas pressure.

A digester fitted with a floating roof of any kind provides a very desirable feature that meets favor with all operators. With this type of installation, supernatant can be drawn off at any time, providing another measure of control over the digester and the treatment process. The control of scum in the digester is also more easily accomplished when it is fitted with a floating roof.

Sludge Pumping

Sludge should be drawn from the primary tanks at frequent intervals to reduce the length of pumping and to remove the sludge before it becomes septic. This ensures that the food supply to the digester is more uniform. The pumping period should be timed to remove the thick sludge only, since long periods of pumping will only draw off settled sewage after all the heavy sludge has been removed. This settled sewage tends to break up the density of the sludge and the thin mixture arriving at the digester only takes up valuable space, requires heating, and is then returned to the plant in a much worse condition than when originally pumped.

The type of pump generally used for the transfer of raw sludge is of a reciprocating plunger or piston type. These pumps are usually fitted with one, two or three pistons. Since they are of a positive pressure type, they are more suited for the transfer of raw sludge. They remove both heavy and light material in the pipe. A centrifugal type pump, however, will suck through the thinner, more watery material leaving the heavier sludge clinging to the sides of the pipe. This sludge that is left tends to turn septic and produces gas which creates an air or gas lock in the pipe, slowing down the removal of the heavy material even more. The piston-type pump must not be operated until all inlet and outlet valves are open.

Heat Exchangers

These units supply the heat for the digester, and, in most cases, for the plant buildings as well. They are normally operated on natural gas and digester gas, or fuel oil and digester gas in that order. The digester contents are drawn off at a medium level through a circulating pump and pushed through coiled pipes in the heat exchanger, which is usually a hot water bath.

Another method of heat transfer is to pump the sludge into the heat exchanger tank in which are located coiled pipes circulating hot water. After passing through the heat exchanger, the sludge is pumped back into the digester and is continuously recirculated until the digester temperature is at its correct level. Further sludge recirculation takes place only when raw sludge is pumped into the digester or if a change is noted in the digester temperature. This recirculation through the heat exchanger also assists in the mixing of the sludge in a digester. Where facilities for only single stage digestion are provided, careful control must be kept on the times and frequencies of sludge recirculation.

Sludge Withdrawal

The withdrawal of sludge from a single stage or a primary digester must be done with extreme care to prevent the removal of sludge which has not been completely digested. If this occurs, the sludge pumped to a drying bed will not dry up properly and will create an odour problem. In addition, it is always necessary to leave some of the digested sludge in the tank to act as a seed sludge for the inoculation of raw sludge being pumped into the digester from the primary clarifiers. This seed sludge is composed mainly of large numbers of healthy bacteria without which the digestion tank would become very rapidly overloaded, resulting in little or no adequate digestion being provided.

Digester Gas (Methane)

The main gas produced during the satisfactory process of digestion is called methane and is formed of carbon and hydrogen. This gas is used as fuel in the

heat exchanger in preference to any other types of fuel, since it costs nothing. Most small plants provide gas storage only under the domed digester roof. Normally, all the gas that is produced is used up immediately either by the heat exchanger or the waste gas burner.

Methods of Collecting & Using Gas

Gas is produced at a fairly even rate in the digester and rises to the top to be collected under the roof. It is maintained here at a certain pressure dependent upon the pressure regulating valve of the waste gas burner. Assuming a pressure equivalent to 8" of water is required to operate the heat exchanger, then the waste gas pressure regulating valve is set to remain closed until 8" of pressure is reached in the line. The pressure relief valve on the roof of the digester is then set at nine inches or one inch greater than the pressure setting of the waste gas regulator. All gas, therefore, under pressure greater than 8" is bypassed or released to the waste gas burner.

If, for any reason, the heat exchanger does not require gas, then the pressure regulating valve is constantly bypassing excess gas to the burner, but an 8" pressure is maintained at all times in the service line and under the roof. If the pressure under the roof should suddenly rise, or the pressure regulating valve stick shut, then the pressure relief valve would permit the escape of gas in excess of 9" of pressure.

In all digesters this unit which houses the pressure relief valve also contains a vacuum relief valve equivalent to three inches of water. This valve may come into operation when the contents of the digester are being removed (for example, sludge removal). Air is then permitted to enter the digester through this vacuum relief valve in order to prevent a large vacuum from occurring inside the tank. This is obviously required since the build-up of a very large vacuum in the tank could result in complete collapse. However, it is undesirable to have air enter

the digester as this develops an air-to-gas explosive mixture. Conditions preventing operation of the vacuum release should therefore be avoided as much as possible.

It is necessary to check the vacuum relief valve regularly to ensure that it is free and in good working order. When a heat exchanger is using natural and digester gas in combination, pressure regulating valves on the gas lines are used to control the pressure of each supply and the pressure of the main feed to the burner. These valves are set so that any pressure drop, below the lowest setting for digester gas, will activate the valve on the digester gas line, thereby switching to natural gas firing. This normally occurs without interrupting the burner operation. Similarly, in the case of a heat exchanger operating on digester gas and oil, the occurrence of a pressure drop in the gas line activates the pressure valve which throws a mercury switch, starting the oil feed pump and switching to oil firing. Again, heat exchanger operation can proceed uninterrupted during such a changeover. When the digester gas returns to a normal 8" pressure, the pressure regulating valve opens and the natural gas regulator closes, or the valve controlling the mercury switch closes shutting off the oil feed pump switching back to digester gas firing. During this transfer of fuel supply, the heat exchanger operation continues uninterrupted.

In the gas lines from the digester to the heater, there are located various traps to catch the accumulation of moisture formed in the gas. These traps should be drained daily. At the pressure regulating valve on the waste gas line, and the pressure relief valve on the roof, there are units called flame arresters. These are designed to prevent the travel of a flame, which may have been caused by some accidental spark and therefore protect the main gas supply in the digester and the heat exchanger from explosion.

These flame arresters are honey-combed metal cores similar to the radiator in an automobile. The openings in these cores are too small to permit a flame to pass through.

Frequent inspections of the pressure and vacuum relief valves and the flame arrester located on the roof of the digester are required during the winter months. This could be done on a regular basis but especially during extremely cold weather.

Sometimes ice will be found coating over the flame arrester cells cutting off all gas flow in that direction. The pressure relief valve frequently freezes. To correct or prevent these conditions, remove the flame arrester cells and soak them in an anti-freeze solution such as Prestone. Replace without wiping dry. If it is found that the pressure relief valve is frozen or will likely freeze, a bit of anti-freeze around the seat of the valve will keep it from freezing.

The P. F. T. liquid-type pressure and vacuum relief valves will not freeze if the kerosene in them is changed regularly and the unit is kept clean and serviceable.

The scum around the edge of a floating digester roof often freezes during cold weather, sometimes so hard as to hold the roof at that level even when the contents are lowered. There is no single cure for this problem. Some operators have used calcium chloride or rock salt sprinkled on the scum around the edge. It works fairly well but care must be taken not to overload the digester with this material; it doesn't help digestion.

The most tried and true method up to date is probably the use of a limited amount of calcium chloride and the Armstrong formula - a length of 2 x 4 and two strong arms worked steadily up and down around the tank roof edge.

Water Gas Burners

If the waste gas burner is acting up due to water settling and freezing in the underground piping, or in the riser pipe through the roof to the burner located there, try a can of Kleen-flo carburetor de-icer fluid through the pipes.

Just pour it down through the jets in the burner pot.

This will dissolve the ice and then evaporate without replacing the ice with fluid.

It may take a can a week to keep the pipe operating, but it is better than digging up the underground pipe in the dead of winter or setting fire to the building trying to unfreeze a roof mounted pipe with a propane torch.

The Kleen-flo can be bought for 75 cents for a pint-size can.

DIGESTER GAS

When the methane gas produced by the digester is used for fuel, its use, the gas piping, regulators, flame arrestors, and all other operating controls and safety devices are subject to the regulations of the Energy and Resources Branch of the Ontario Government.

Digester Cleanout

When it becomes necessary to remove the contents of a digester and enter it for cleanout or repairs the entrance to the digester must be made in accordance to Section 12, Subsections 1, 2 & 3 of the Industrial Safety Act, Department of Labour.

All entrances to any tank or area considered as a confined space must be made as per Section 12.

Chlorine Gas

Chlorine is used for a large variety of purposes in a sewage treatment plant. The foremost function is disinfection, but its characteristics make it adaptable for other uses. Following are a few of these uses:

1. Reduction of odours by reducing the number of bacteria decomposing in the sewage. This chlorine is normally applied to the sewage before reaching the plant and maintains the bacteria dormant until they reach the plant for further treatment.

2. It helps to decrease the BOD.

3. It improves the settling of activated sludge in the final settling tank when it is applied to the activated return sludge. Chlorine is generally used here for the control of bulking in the final tanks.

There are various types of chlorinating machines, but they all have the same basic operation in that they convert the chlorine, as delivered in its containers, to a solution by the addition of water. This is done for easier application.

Points of Applications

1. Chlorination at the influent channel ahead of the primary tanks for odour control and prevention of septic conditions.
2. Chlorination of the effluent for disinfection and bacterial control.
3. Chlorination of return activated sludge.

Chlorine is delivered to the plant in cylinders, which are normally used in series of two or more at a time in an upright position. Larger (one-ton) containers are also obtainable, and these are used singly or occasionally in series of two or three. These are normally employed in a horizontal position. Chlorine gas is very dangerous and any repair to leaking cylinders or chlorine lines must be made while wearing a gas mask of the proper type. It is essential to remember that no work should be done around chlorine cylinders or lines unless two men are working together. For further information on chlorine, reference should be made to the technical service bulletin on liquid chlorine by Canadian Industries Limited.

SAFETY PRACTICES IN PLANT BUILDINGS

Sewage treatment plant - No smoking areas.

- (a) Influent Buildings
- (b) Detritor rooms
- (c) Wet and dry wells of plant pumping station
- (d) Pump rooms containing raw sludge pumps.
- (e) Tunnels having pipe galleries carrying digester gas or natural gas pipe.

- (f) Digesters, digester buildings
- (g) Sewers, manholes
- (h) Sludge holding tanks (covered)
- (i) Near sludge thickening tanks while being mixed with compressed air
- (j) Sludge conditioning tanks in filter rooms
- (k) Sludge loading pipes to trucks
- (l) Sludge discharge pipes to drying beds

Handling of Electrical Circuits

- i. Consider all electrical circuits to be dangerous. Contact with lower currents have caused workmen to fall from ladders and scaffolds.
- ii. Shut off the power when examining or making repairs or alterations on light and power circuits. When this is impractical your supervisor must be contacted for further instructions before proceeding with the work.
- iii. Treat dead circuits as though they were alive. This may prevent an accident as the circuit may be closed through an error of some other person.
- iv. Exercise extreme care when required to locate troubles on a series lamp circuit, before repairs are made make sure the power is cut off.
- v. Lock or block open the control devices, open disconnect switches or remove fuses before examining, repairing or working on power circuits. After these precautions have been taken, attach tie-up tags worded "Workmen are Working on Line;" the tag shall bear the name of the workman.

CLASSIFICATION OF ACCIDENT CAUSES

1. Unsafe Acts

- (a) Working without authority.
- (b) Operating or working at unsafe speed.
- (c) Making safety devices inoperative.
- (d) Using improper tools or appliances.

- (e) Unsafe material handling.
- (f) Unsafe piling of materials.
- (g) Assuming hazardous position or posture.
- (h) Working on moving or dangerous equipment.
- (i) Distraction, teasing, abusing and startling.
- (j) Failure to use, or improper use of, safe attire or personal protective equipment.
- (k) Failure to give or receive proper signals.
- (l) Working without instructions.
- (m) Failure to co-ordinate and co-operate.
- (n) Error in judgment.
- (o) Violations of specific instructions.
- (p) Failure to recognize an unsafe condition or practice.
- (q) Lack of inspection and maintenance.
- (r) Failure to establish safe working procedures.
- (s) Working while unfit for duty.

2. Unsafe Conditions

- (a) Improperly guarded equipment.
- (b) Faulty design and installation of equipment or structure.
- (c) Failure of machinery, equipment, structures and materials.
- (d) Hazardous arrangement, poor housekeeping, etc.
- (e) Improper illumination.
- (f) Hazardous dusts, gases, fumes and mists.
- (g) Physical defects of employees.
- (h) Natural conditions beyond human control (Acts of God)

PUMPS

Centrifugal Pumps:

The efficiency and life of this type of pump is governed directly by the amount of care and servicing they receive from the operator.

The following is intended as a guide for the operator in order that he will be better able to look after his equipment.

Pump Protection:

All pumps require protection from hard objects and abrasive material frequently found in sewage. These can damage the pumps and obstruct the flow.

Most pumping stations and treatment plants have a bar screen which has been previously discussed. When removing material from these screens, do not rake any trapped material through the screen and permit it to enter the pump.

Operation of Pumps

A centrifugal pump must be primed before starting and the casing and suction pipe must be completely filled with water or the fluid it is intended to pump.

1. Open intake pipe valve and leave discharge pipe valve closed.
2. Open the petcock on the pump casing and allow the air to escape. Leave this open until a solid jet of water is being released. With the pump primed, but the discharge valve still closed, start the pump motor. The motor should just be cut in and out a few times for short intervals. Check the pump rotation and coasting, making note of any unusual noises. If the pump runs and coasts satisfactorily then the discharge valve may be opened and the pump can then be put into service. Whenever it becomes necessary to decrease the rate of discharge, or to throttle down a pump, this can be accomplished by partially closing the discharge valve, never by closing the intake valve.

Maintenance:

The unit should be checked daily for noise level or the development of heat in any part of the unit, that is bearings, couplings, packing, etc. (See instructions on Trouble Report Sheet).

Stuffing Boxes or Packing Glands:

These important units must be inspected and serviced with care since improper servicing causes extensive wear on the pumps and reduces their efficiency. The number of packing rings varies with the size and type of pump, but they all contain a seal ring. This is a metal ring of approximately 1/8 of an inch to 3/16 of an inch thick with slots spaced in it. It is placed approximately in the middle of the gland in line with the grease or water pipe leading into the gland. Its purpose is to receive clear water or grease which makes a seal preventing air from entering the gland from the top and sewage water with its grit from entering the gland from the bottom. It also lubricates the shaft and packing. If the packing is allowed to remain in the pump too long after the top gland has been brought down as far as it will go, or if too many extra pieces are placed on top of the existing ones, excessive leaking will occur as the existing packing becomes more compressed. The wearing edge becomes hard and brittle with a carbon-like formation on the surface. This carbon surface acts as an abrasive on the shaft sleeve and soon cuts deep grooves. Any packing which is neglected to this stage becomes very difficult to remove.

Re-packing of Pumps:

The gland nuts, clamps and glands must be removed before the packing can be renewed. In most cases the glands are split making removal easier. The old packing, including the lantern ring, should be picked out from the stuffing box making note of the number of pieces above and below the lantern ring. The stuffing box should be cleaned out and the shaft inspected and wiped. Note should be made of any wearing on the sleeve. A length of packing should be wrapped around the shaft and cut so that the ends just meet. If it is necessary to tamp or roll the packing before insertion, this should be completed before the packing is cut out to fit the shaft.

It is always necessary to use the same type of packing as was previously installed or as is recommended by the pump manufacturer. Each piece of packing should be placed in the stuffing box and pushed into place with the gland, making sure that the packing joints are staggered. After all sections of packing and the lantern ring have been inserted in the correct sequence in the box, the gland clamps and nuts should be replaced.

The gland nuts should be tightened down evenly until all the slack is taken up one flat at a time approximately $1/6$ of a turn. Turn the shaft by hand and if it turns freely, start the pump and continue to tighten the gland nuts until excessive leakage stops and only a few drops of water escape per minute. This can be achieved by making the gland nuts finger tight; this means using a spanner wrench of the proper size for the nut being used and drawing the nut tight by holding the wrench in the tips of the fingers. A little practice at this and it will be found that the nut is just snug. Stop the pump and again turn the shaft by hand. If it is still free, put the pump into operation.

When replacing the packing, it will often be found that although five pieces of packing were removed, only four pieces will go back in, leaving the gland about half way down in the stuffing box. Be sure to cut the required amount of packing at the time of renewal and place the one that won't go in on the top of the pump or in some other handy place. It will be found that after a few days depending on how often the pump is used, the gland will be drawn down its full depth and then the last piece of packing can be inserted. After inserting this piece, tighten the gland nuts and take the same precaution as for a full re-packing procedure. If all pieces will go back in the stuffing box without forcing, then the sleeve on the shaft is becoming worn and should be reported to the Engineer.

Do not leave the pump for a few minutes as friction heat takes a short time to build up. If after several minutes the gland is still cool, or no more than body temperature, it is safe to leave the pump in service. Make sure that the water seal or grease unit is working properly and, if there is a grease fitting, give several shots of grease with the gun while the pump is running.

Lubrication:

The type of grease or oil to be used and the frequency with which the pumps should be greased is contained in the maintenance cards and should be followed carefully.

CHARACTERISTICS OF DANGEROUS GASES ENCOUNTERED IN SEWERS, SEWAGE PUMPING STATIONS AND SEWAGE TREATMENT PLANTS

GAS	CHEMICAL FORMULA	COMMON PROPERTIES*	SPECIFIC GRAVITY OR VAPOUR DENSITY (AIR = 1)	PHYSIOLOGICAL EFFECT*	MAX SAFE 60-MIN EXPOSURE (% BY VOL. IN AIR)	MAX SAFE 8-HR EXPOSURE (% BY VOL. IN AIR)	EXPLOSIVE RANGE (% BY VOL. IN AIR) LOWER UPPER LIMIT LIMIT	LIKELY LOCATION OF HIGHEST CONCENTRATION	MOST COMMON SOURCES
CARBON DIOXIDE	CO ₂	COLORLESS, ODORLESS. WHEN BREATHED IN LARGE QUANTITIES MAY CAUSE ACID TASTE. NONFLAMMABLE. NOT GENERALLY PRESENT IN DANGEROUS AMOUNTS UNLESS AN OXYGEN DEFICIENCY EXISTS.	1.53	CANNOT BE ENDURED AT 10% MORE THAN FEW MIN, EVEN IF SUBJECT IS AT REST AND OXYGEN CONTENT NORMAL. ACTS ON RESPIRATORY NERVES.	4.0 TO 6.0	0.5	- -	AT BOTTOM; WHEN HEATED MAY STRATIFY AT POINTS ABOVE BOTTOM	PRODUCTS OF COMBUSTION, SEWER GAS, SLUDGE. ALSO ISSUES FROM CARBONACEOUS STRATA.
CARBON MONOXIDE	CO	COLORLESS, ODORLESS, TASTELESS, FLAMMABLE, POISONOUS.	0.97	COMBINES WITH HEMOGLOBIN OF BLOOD. UNCONSCIOUSNESS IN 30 MIN AT 0.2 TO 0.25%. FATAL IN 4 HR AT 0.1%. HEADACHE IN FEW HR AT 0.02%.	0.04	0.01	12.5 70.0	NEAR TOP, ESPECIALLY IF PRESENT WITH ILLUMINATING GAS.	MANUFACTURED GAS, FLUE GAS, PRODUCTS OF COMBUSTION, MOTOR EXHAUST. FIRES OF ALMOST ANY KIND.
CHLORINE	CL ₂	YELLOW GREEN COLOR. CHOKING ODOR DETECTABLE IN VERY LOW CONC. NONFLAMMABLE.	2.49	IRRITATES RESPIRATORY TRACT. KILLS MOST ANIMALS IN VERY SHORT TIME AT 0.1%.	0.0004	0.0001	- -	AT BOTTOM.	CHLORINE CYLINDER AND FEED LIKE LEAKS.
GASOLINE	C ₅ H ₁₂ TO C ₉ H ₂₀	COLORLESS. ODOR NOTICEABLE AT 0.03%. FLAMMABLE.	3.0 TO 4.0	ANESTHETIC EFFECTS WHEN INHALED. RAPIDLY FATAL AT 2.4%. DANGEROUS FOR SHORT EXPOSURE AT 1.1 TO 2.2%.	0.4 TO 0.7	0.10	1.3 6.0	AT BOTTOM.	SERVICE STATIONS, GARAGES, STORAGE TANKS, AND HOUSES.
HYDROGEN	H ₂	COLORLESS, ODORLESS, TASTELESS. FLAMMABLE.	0.07	ACTS MECHANICALLY TO DEPRIVE TISSUES OF OXYGEN. DOES NOT SUPPORT LIFE.	-	-	4.0 74.0	AT TOP.	MANUFACTURED GAS, SLUDGE DIGESTION TANK GAS, ELECTROLYSIS OF WATER. RARELY FROM ROCK STRATA.

* PERCENTAGES SHOWN REPRESENT VOLUME OF GAS IN AIR.

CHARACTERISTICS OF DANGEROUS GASES (CONTD.)

GAS	CHEMICAL FORMULA	COMMON PROPERTIES*	SPECIFIC GRAVITY OR VAPOUR DENSITY (AIR = 1)	PHYSIOLOGICAL EFFECT*	MAX SAFE 60-MIN EXPOSURE (% BY VOL. IN AIR)	MAX SAFE 8-HR EXPOSURE (% BY VOL. IN AIR)	EXPLOSIVE RANGE (% BY VOL. IN AIR) LOWER LIMIT UPPER LIMIT	LIKELY LOCATION OF HIGHEST CONCENTRATION	MOST COMMON SOURCES
HYDROGEN SULFIDE	H ₂ S	ROTTON EGG ODOR IN SMALL CONC. EXPOSURE FOR 2 TO 15 MIN AT 0.01% IMPAIRS SENSE OF SMELL. ODOR NOT EVIDENT AT HIGH CONC. COLORLESS. FLAMMABLE.	1.19	IMPAIRS SENSE OF SMELL RAPDILY AS CONC. INCREASES. DEATH IN FEW MIN AT 0.2%. EXPOSURE TO 0.07 TO 0.1% RAPIDLY CAUSES ACUTE POISONING. PARALYZES RESPIRATORY CENTER.	0.02 TO 0.03	0.002	4.3 46.0	NEAR BOTTOM, BUT MAY BE ABOVE BOTTOM IF AIR IS HEATED AND HIGHLY HUMID.	COAL GAS, PETROLEUM SEWER GAS, FUMES FROM BLASTING UNDER SOME CONDITIONS SLUDGE GAS.
METHANE	CH ₄	COLORLESS, ODORLESS, TASTELESS. FLAMMABLE.	0.55	ACTS MECHANICALLY TO DEPRIVE TISSUES OF OXYGEN. DOES NOT SUPPORT LIFE.	PROBABLY NO LIMIT PROVIDED OXYGEN PERCENTAGE IS SUFFICIENT FOR LIFE.		5.0 15.0	AT TOP, INCREASING TO CERTAIN DEPTH.	NATURAL GAS, SLUDGE GAS, MANUFACTURED GAS, SEWER GAS. STRATA OF SEDIMENTARY ORIGIN. IN SWAMPS OR MARSHES.
NITROGEN	N ₂	COLORLESS, TASTELESS. NONFLAMMABLE. PRINCIPAL CONSTITUENT OF AIR (ABOUT 79%).	0.97	PHYSIOLOGICALLY INERT.	-	-	- -	NEAR TOP, BUT MAY BE FOUND NEAR BOTTOM.	SEWER GAS, SLUDGE GAS. ALSO ISSUES FROM SOME ROCK STRATA.
OXYGEN (IN AIR)	O ₂	COLORLESS, ODORLESS, TASTELESS. SUPPORTS COMBUSTION.	1.11	NORMAL AIR CONTAINS 20.93% OF O ₂ . MAN CAN TOLERATE DOWN TO 12%. MIN SAFE 8-HR EXPOSURE, 14 TO 16%. BELOW 10% DANGEROUS TO LIFE. BELOW 5 TO 7% PROBABLY FATAL.	-	-	- -	VARIABLE AT DIFFERENT LEVELS.	OXYGEN DEPLETION FROM POOR VENTILATION AND ABSORPTION, OR CHEMICAL CONSUMPTION OF OXYGEN.
SLUDGE GAS	-	MAY BE PRACTICALLY ODORLESS, COLORLESS. FLAMMABLE.	VARIABLE	WILL NOT SUPPORT LIFE.	NO DATA. WOULD VARY WIDELY WITH COMPOSITION.	-	5.3 19.3	NEAR TOP OF STRUCTURE.	FROM DIGESTION OF SLUDGE.

* PERCENTAGES SHOWN REPRESENT VOLUME OF GAS IN AIR.



ONTARIO
DEPARTMENT OF LABOUR
ENGINEERING SERVICES BRANCH

STORAGE AND USE OF CHLORINE

Introduction

Chlorine has wide use in industry. 150 lb. cylinders are commonly used. Where usage exceeds 150 lbs. daily, one-ton containers have been introduced to minimize handling.

Properties

Chlorine liquid has a specific gravity of 1.47 (water = 1)

Chlorine gas has a density of 2.49 (air = 1)

One volume of liquid chlorine gives off 456.8 volumes of gaseous chlorine at 32°F and 1 atmosphere pressure.

One pound of liquid chlorine is equivalent to 4.98 cubic feet of gaseous chlorine at 32°F and 1 atmosphere pressure.

Dry chlorine does not corrode steel or common metals at ordinary temperatures. In the presence of moisture, hydrochloric acid is formed causing corrosion.

Characteristics

Chlorine is non inflammable, and is a powerful respiratory irritant.

1. Location

- (a) Storage should preferably be in an isolated building or in a room without direct access to a factory area. Construction should be of fire-resistive material and the building or room should have concrete floors and good drainage.
- (b) Ton containers shall be stored on their sides on level racks, e.g. parallel "I" beams. There should not be less than 4 in. and not more than 8 in. air space between the container and grade.
- (c) Chlorine should not be stored below ground level.
- (d) Chlorine should not be stored with combustible materials.

- (e) The container shall be protected against excessive external heat sources, dampness and mechanical damage. Outside storage should be sheltered from the direct rays of the sun.
- (f) Separate storage space shall be provided for full and empty containers.
- (g) Storage areas shall not be located in areas where escaping gas could enter a ventilating system.
- (h) Chlorine storage areas shall be clearly marked "Danger! Chlorine Storage!"
- (i) The scale room should be adjacent to the storage area and be of fire resistive construction.

2. Exits

The exit doors shall be hinged to open outwardly. There shall be two or more exits if the distance of travel to an exit exceeds 15 ft.

The distance of travel to the nearest of two or more exits shall not exceed 75 ft.

3. Ventilation

- (a) Continuous mechanical ventilation at the rate of 3 air changes per hour shall be provided, or, screened openings to the outdoors shall be provided within 6 inches of the floor in the ratio of 1 sq. ft. per 500 sq. ft. of floor area. Similar openings shall be provided in or near the ceiling. The openings shall be distributed to produce the maximum air circulation across the floor.
- (b) Provision for emergency mechanical ventilation should be made sufficient to produce 30 air changes an hour taking suction at a maximum of 3'-0" above floor level.

4. Protective Equipment

- (a) Emergency canister gas masks of a type approved for chlorine service by

the United States Bureau of Mines shall be readily available where chlorine is being stored or used. The gas masks shall be kept in dust-tight cabinets and the cabinets locked in a conspicuous location outside the area of probable contamination.

- (b) Only self-contained or air-supplied types of respiratory protective equipment shall be used where the chlorine concentration may be above 1 per cent (10,000 p.p.m.). Gas masks are of no use in these cases.
- (c) Protective goggles, aprons, gloves and safety shoes shall be available for persons loading, storing, or handling chlorine.
- (d) Deluge type safety showers and eye wash fountains shall be available in case of accident. These shall be located as near as possible but outside the area of probable contamination.

5. Chlorine Leaks

A plan of action shall be prepared to deal with emergency leaks. A chlorine tool kit recommended by the supplier shall be available.

6. First-Aid

Remove the affected person from the contaminated area. Keep him warm and quiet. If the victim is conscious, do everything possible to discourage coughing. Oxygen is of great value. Even in mild cases, inhalation of oxygen relieves chest irritation. In severe exposure cases, oxygen should be administered until the victim is able to breathe easily. Contaminated clothing should be removed and contaminated body areas flushed with water. If breathing seems to have stopped or has ceased, apply artificial respiration without delay along with oxygen. The services of a physician should be obtained as quickly as possible.

7. Chlorine Disposal

Chlorine may be absorbed in solutions of caustic soda, soda ash, or hydrated lime. A solution of caustic soda absorbs chlorine most readily.

RECOMMENDED SOLUTIONS FOR ABSORBING CHLORINE (ONE-TON CONTAINER)	
ABSORBING CHEMICAL	WATER
Caustic Soda — 2500 lb.	800 gallons.
Soda Ash — 6000 lb.	2000 gallons
Hydrated Lime — 2500 lb.	2500 gallons

TECHNICAL APPENDIX I

DIGEST OF
GENERAL TECHNICAL INFORMATION

SLUDGE BULKING -- PROBABLE CAUSES

Primary Tanks

- a. Septic or stale raw sewage
- b. Industrial Wastes
- c. High organic load -- BOD, suspended solids
- d. Varying flows, surging from lift stations, etc.
- e. Abnormal pH
- f. Excessive grease, fuel oils and other petroleum products

Aeration Tanks

- a. Insufficient air (low D. O.)
- b. Too short an aeration period
- c. Too long an aeration period (high D. O.)
- d. High suspended solids in mixed liquor
- e. Poor mixing of tank contents
- f. Low suspended solids in mixed liquor
- g. D. O. in return sludge unstable

Final Tank Operations

- a. Return sludge rate too slow, plant at capacity or over heavy organic or industrial loadings.
- b. Return sludge rate too fast, plant under capacity, light organic load or domestic flow only
- c. High flow due to wet weather runoff
- d. Partially plugged sludge draw-off pipes or slip tubes

Tank Configuration

A. Square Tanks

1. Counterweight chain on swing arm of sludge collector jammed or broken, causing sludge build-up in corners of tank.

B. Rectangular Tanks

1. Sludge valves in sumps not opened or not opening fully
2. Build-up of sludge on sump walls
3. Build-up of sludge in slip tube channel
4. Deflecting baffle at influent end of tank not extended deep enough in tank.

USEFUL FORMULAS

Tapleshay's formula for chlorination of return sludge

$$CD = SI \times F \times W \times 0.0000834$$

where CD= chlorine dosage in lbs/day

SI = Mohlman sludge index

F = Return sludge (mgd)

W = Suspended solids in return sludge (ppm)

Return sludge flow to be constant, with contact point at point of entry of return pipe.
Two-minute contact time if possible (reaction time).

Hydrated lime for pH control of digesters

Do not use in dry form. Mix the lime in a drum or tub with water to a thin solution of milk of lime. Then add solution to digester via scum pit of primary tank. This is known as liming the tank.

Dosage is five to 10 lbs. per 1,000 persons or 1,000,000 gallons of plant influent flow for each application, usually once per day.

Calculation of domestic organic loading per day

Population equivalent or amount of organic material contributed by each person daily to the sanitary system is approximately 0.17 lbs. of 5-day BOD.

Horsepower of heat exchanger -- Natural and Digester gas

$$1 \text{ hp} = 2,546 \text{ BTU per hour}$$

$$\text{Heat exchanger with output of } 750,000 \text{ BTU per hour} = 216 \text{ hp}$$

$$\text{" " " " " } 1,000,000 \text{ " " " } = 392 \text{ hp}$$

$$\text{" " " " " } 1,500,000 \text{ " " " } = 589 \text{ hp}$$

Heat exchange rating:

$$\begin{array}{rcl} & \text{at 1,000 BTU} & \text{at 650 BTU} \\ & \text{natural gas} & \text{digester gas} \\ 750,000 \text{ BTU} = & 750 \text{ cu. ft. per hour} & = 1,250 \text{ cu. ft. per hour} \end{array}$$

$$1,000,000 \text{ BTU} = 1,000 \text{ cu. ft. per hour} = 1,666 \text{ cu. ft. per hour}$$

- - - - -

Conversion of Volume to Dry Weight of CaO for Vacuum Filtering

Lime mix = 50 lbs. to 30 gals. of water for a 70% lime mix
(Imperial gallons)

$$50 \text{ lbs.} \div 30 \text{ gals.} = 1.66 \text{ lbs. per gallon of CaO}$$

$$70\% \times 50 \text{ lbs.} = 35 \text{ lbs.}$$

$$35 \text{ lbs.} \div 30 \text{ gals.} = \underline{1.16 \text{ lbs. per gallon @ 70\%}}$$

To maintain the same ratio of lime and water when using U. S. measurements, use
40 lb. bags of lime instead of 50 lb. bags.

Example: 40 lbs. ÷ 24 gallons = 1.66 lbs. per gallon CaO
28 lbs. ÷ 24 gallons = 1.16 lbs. per gallon @ 70%

Sludge age in days

Formula: $\frac{V \times A}{Q \times C}$

Where V = aeration tank volume in gallons
A = suspended solids in the mixed liquor
Q = total sewage flow per day
C = suspended solids in primary tank effluent

Example: V = aeration tank capacity of 1,000,000 gallons
A = suspended solids in mixed liquor at 1,500 ppm
Q = daily flow of 2,000,000 gallons
C = average suspended solids primary effluent of 20 ppm

Calculation:

1 ppm = 10 lbs. per million gal. water
V = capacity 1000,000 gal. or 10 lbs. suspended solids / 1000,000.
A = MLSS 1500 ppm x 10 lbs. = 1500 lbs. = suspended solids
= the total solids in the aeration tank.
Q = daily flow 2000,000 gals. x 10 lbs. = 20 lbs. suspended solids
C = average SS primary effluent 200 ppm x 20 lbs. = 4000 lbs.
suspended solids
Sludge age is = $\frac{15000 \text{ lbs.}}{4000 \text{ lbs.}}$ = 3.75 days

An increase in the suspended solids of the mixed liquor will increase the sludge age.

A decrease in the suspended solids of the mixed liquor will decrease the sludge age.

BUT a decrease of the suspended solids in the primary effluent will increase the sludge age, and an increase of suspended solids in the primary effluent will decrease the sludge age.

Example of laboratory procedure for determining amount of hydrated lime and ferric chloride required for conditioning sludge for vacuum filtering

Using the Bouchner funnel test, three samples are used:

No. 1 Sample

The filter paper is dampened and placed in the Bouchner funnel, and the aspirator is connected.

100 mls of raw sludge is poured into a beaker and 2 mls of ferric chloride are added.

4 mls of lime are added, stirring slowly during additions of chemicals.

When thoroughly mixed, pour sample into Bouchner funnel and start aspiration.

Time the operation from the first drop of water to leave the funnel until vacuum gauge pressure drops, controlling pressure on the vacuum gauge to 13 lbs. Break point here 50 seconds time to short.

No. 2 Sample

Same procedure.

Ferric chloride content reduced to 1 1/2 mls from 2 mls, lime content left at 4 mls. Break point 70 seconds (just about right).

No. 3 Sample

Same procedure.

Ferric chloride content reduced to 1 ml from 1 1/2 mls, lime content increased to 5 mls from 4 mls. Break point at 175 seconds (too long).

Best filtering is usually with a pH of 11. To raise pH of conditioned sludge in filter vat, increase lime feed 5% to conditioning tank.

An increase of raw sludge feed in gallons per minute may be made without changing lime or ferric feed. Changes in lime or ferric feed will be necessary only if there is a change in the sludge blanket on the filter.

Vacuum Filtration

Where large volumes of sludge must be handled, vacuum filters reduce the volume by dewatering.

The filter consists of a porous drum around which is wrapped a cloth or steel-coil blanket. With the aid of chemical coagulants, the drum blanket picks up the sludge from a trough and, as the drum and blanket rotates, the sludge is dewatered by exerting a partial vacuum upon the blanket. A scraper edge removes the dewatered sludge cake and it drops on to a conveyor for delivery to a disposal area.

DIGESTER OPERATION

Volatile Acid Control

The use of the volatile acid test of digester contents as a controlling factor is the only way to foretell adverse conditions that may be developing in the digester before a change of pH is noticed.

A concentration value of 500 ppm to 1000 ppm may be considered normal.

A drop of volatile acid level below 500 ppm to 100 ppm is usually an indication that the digester is considerably underloaded organically, and under continued operation with this condition the digestion process will slow down. Gas production will also slow down if it doesn't stop altogether, with surges of gas for a short time after a number of sludge pumpings.

An increase of volatile solids in a working digester to 1500 or 2000 ppm is a warning that conditions have changed in the tank, which could be caused by the following:

1. Sludge pumping too long on each pumping; don't increase the pumping time, add another pumping cycle of three to five minutes maximum.
2. Improper mixing of contents, usually insufficient mixing for amount of solids pumped.

Fixed roof digesters not equipped with mechanical or gas mixing devices present quite a problem in efficient operation. As in an aeration tank the contents of a digester must be completely mixed to bring the micro-organisms and the available food supply into intimate contact.

This cannot be done by circulating the contents of the digester through the heat exchangers. This circulation of sludge was designed for heating the contents only. If sludge recirculation is the only means of mixing and the daily sludge load is heavy certain conditions can develop.

The sludge in the tank between the draw-off point and the discharge point when being recirculated will be well digested and up to temperature. The sludge in the tank on the edge of this moving sludge will also move but more slowly and the temperature will be slightly less.

The sludge in the outer perimeter of the tank will not be moved and the temperature in this region will be considerably lower slowing down the rate of digestion to half of that of the sludge in the centre, particularly if the tank has been poorly insulated and/or located in a northern climate.

Raw sludge pumpings of 10 to 30 minutes or more aggravate this condition.

The slower digestion of the sludge in the outer perimeter of the tank develops a condition similar to a septic tank operation. The digestion process never develops out of the acid range.

The sludge instead of being digested to a point where it will settle breaks up into small pieces and is carried to the surface by gas bubbles mostly H_2S , (Hydrogen Sulfide) and CO_2 (Carbon Dioxide). As these pieces of floating sludge join the material that is normally floating on the liquid surface such as small sticks, hair, grease, etc., it soon forms a heavy scum blanket sometimes 10 to 12 feet thick.

The scum as it thickens rises above the surface insulates itself from the temperature of the tank and becomes partially dry and digestion of the material practically stops.

This build-up of scum can cause many other problems within the digester. Building up until it enters and plugs the overflow pipe, this causes the liquid level to rise and if not noticed the scum will enter the gas collection pipe and block it.

A heavy scum blanket will prevent the gas being produced from rising to the surface. If sufficient gas is trapped under the scum, it can force the scum layer up against the roof hard enough to break the seal around the roof edge and cause large cracks in the roof surface.

The larger the tank the more serious these conditions can become.

Digesters equipped with floating roofs that float on the liquid surface are not usually equipped with mechanical mixers, but can have digester gas recirculation through a gas compressor, referred to as gas mixing. However, not all floating roofs are so equipped and without mixing, the conditions described for fixed roof tanks can also develop in a tank with a floating roof. Normally the scum blanket will not develop to such a volume under a floating roof as the roof rests on the liquid surface and keeps the scum submerged under the liquid. This maintains the temperature and in contact with the active micro-organisms and digestion is continued.

A discharge point of the recirculated sludge through the heat exchanger is located above the liquid level in the centre dome of the roof. The flow of sludge from this point keeps an area of the scum blanket broken up allowing the gases to rise up into the gas dome for collection.

However, the scum can and has accumulated under a floating roof until it was pushed up and to one side allowing the gases to escape from beneath the roof by the digester wall.

If excessive scum conditions develop in a digester, it can be broken up and disposed of temporarily by using compressed air.

This will not remove the cause and the scum will reform again.

One method of keeping the sludge moving in the dead areas of a digester with fixed or floating roofs is to install two more discharge pipes in the tank on the sludge recirculation system.

One discharge pipe should be located on either side and half way between the draw-off pipe and the existing discharge pipe located on the far side of the tank. Each discharge point could be used alternately daily or weekly.

Temperature control is vital. Allowing the temperature to drop below normal operational levels will slow down the rate of digestion.

Industrial wastes

If a continued rise of the volatile acids and a drop in the alkalinity is recorded, some action is required to stop the change and restabilize the contents. A few suggested steps to this end:

- a. Direct raw sludge pumping to another digester if possible.
- b. If it is possible to use the second tank, then continue to recirculate No. 1 tank. Operate the mixers 24 hours per day. If mechanical, reverse direction, for several hours per day.
- c. Add milk of lime, as per formula previously mentioned, at the primary scum and grease trap.
- d. If temperature is below 90 degrees, bring it up to a 90-95 degrees range.
- e. If it isn't possible to use another digester, cut down the number and length of the daily raw sludge pumpings. As far as possible, spread the daily pumpings over the 24 hours.
- f. Add the milk of lime under these conditions twice per day -- about 25 lbs. of lime to each mix, or 50 lbs. per day.
- g. The continued use of mixers is not possible because of upset supernatant, so a rest period would be advisable before each pumping (except for floating roofs).
- h. It may be necessary to haul the raw sludge away by truck until the digester returns to normal operation. If caught soon enough, it will take from 7 to 15 days to bring it back.
- i. If the contents have reached a volatile acid range high enough to cause foaming (3,000 or more), about the only recourse left for the operator is to pump up sufficient cold raw sewage to lower the temperature below normal operational levels, i. e., from 90-95 degrees down to 80 degrees or less. Stop all recirculation and mixing.

As the tank cools down, so will the rate of digestion. The volatile acid build-up will stop at a high level, but once the conditions become steady, the same procedure may be followed as outlined.

However, no further sludge must be added, and as the temperature is again brought up slowly, the volatile acid readings must be taken each day. There will be an increase in the acids, but with constant mixing and the use of the milk of lime, it should not exceed 300 to 400 ppm over the reading taken with the tank immobilized.

- j. If the steps recommended in the last section do not succeed in stabilizing the tank after 10 to 20 days, it is unlikely that it can be stabilized in less than several months, if at all. The only action left is to clean out the tank and start over again.

When starting up a new or cleaned-out digester, always fill the tank with water to the overflow (with a fixed roof) or until the roof floats off the corbels (floating type). Sewage water will do. Heat contents to 90 degrees before pumping in raw sludge. Control digestion from this point by volatile acid tests.

Sludge Drying Beds

In smaller installations sludge drying beds provide the means for dewatering the sludge. The beds, which are equipped with underdrains, have the sludge run on them and through moisture evaporation and the underdrain system the sludge is dried.

TECHNICAL APPENDIX II

LABORATORY TECHNIQUES

SUSPENDED SOLIDS

The analysis of the amount of suspended solids in raw sewage, primary effluent, final effluent, mixed liquor and return sludge is best calculated by the following method:

1. Use a 12.5 cm Whatmans #40 filter paper or equivalent.
2. Prepare only the number of filter papers that will be needed for one day's run. Number each paper.
3. Place filter papers in the drying oven at 103° C for 15 minutes.
4. At the end of the above drying period, transfer the papers quickly to the desiccator.
5. Cool for at least 15 minutes.
6. Weigh each paper and record the weights.

Filtration procedure

- a. Set up a vacuum flask complete with a Buchner funnel and a rubber stopper to fit the flask.
- b. Use suction tubing, 1/4" I. D. x 1/8" wall, to connect vacuum flask to suction device on the tap.
- c. Place the funnel on the flask. Take one of the pre-weighed filter papers and using a 400 ml beaker or any object which has a diameter equal to this, form the paper over the beaker to produce a shallow dish-like form. Place this in the Buchner funnel and apply suction. Pour in approximately 100-250 mls of distilled water and tamp the paper down carefully around the edges until all the holes are covered and a vacuum has been produced. This can usually be established by the sound of the water being drawn through the paper.
- d. Pipet 50 mls of the well-shaken sample on to the filter paper, taking care that none is allowed to overflow the rim of the paper dish.
NOTE: If the liquid to be filtered is full of large pieces of material, the sample should be blended for 15 to 30 seconds in a Waring Blender and the aliquot pipeted before the heavy particles have a chance to settle.
- e. When the liquid has been sucked through the filter paper, as indicated by the dry (not glossy) appearance of the surface, use a pair of tweezers to lift the filter paper out of the funnel and place it in the oven.
- f. Dry for at least 30 minutes and no more than one hour.
- g. Transfer the dried paper to the desiccator and leave it for 30 minutes.
- h. Weigh as quickly as possible and record the weight.

Calculation

The weight of the filter paper plus sample after drying, minus the original weight of the filter paper, gives the weight in grams of the solids.

Example:

Weight of sample plus paper = 1.1347 grams
Original weight of filter paper = 0.9487 grams
 $1.1347 - 0.9487 = 0.1860$ grams. This is the same as 186 milligrams of dry solids.

As 186 milligrams is contributed by 50 millilitres of original sample, the concentration is 186 mg/50 ml. To express this in terms of milligrams per litre, you must multiply by 20 because $50 \times 20 = 1,000$.

The calculation then becomes $186 \times 20 = 3720$ mg/l.
A rule of thumb now becomes apparent.
Drop the decimal point and multiply by 2.

Example:

If the dry solids weight was 0.1860, this would be $1860 \times 2 = 3720$ mg/l
If the dry solids weight was 0.0186, this would be $186 \times 2 = 372$ mg/l, or
with dry solids of 0.0019 it would be $19 \times 2 = 38$ mg/l.

TOTAL AND VOLATILE SOLIDS

The following method is used to determine the total and volatile solids in the raw and digested sludges, including the supernatant.

For ease of handling, flat-bottom dishes are preferred, but round-bottom dishes may be used.

Cleaning the Dishes

All dishes are ignited in the muffle furnace each time they are used. They are then cleaned by scouring with a wire brush. The dust and ash are wiped off with a clean cloth and the dish put aside for weighing. If the above procedure is followed, it will be found that the tare weights change very little. They may be stored anywhere that is free of dust.

This method of cleaning and storing dishes will apply only to those dishes which are used for sludges.

Drying and Igniting

The sludges should be dried in an oven at 103°C overnight, removed from the oven, placed in the desiccator, and cooled for at least one hour before weighing. All ignitions should be done at 600°C . The sludges must be dry before attempting ignition. The time for complete burning will vary somewhat, depending on the density of the sludges.

However, a minimum of one hour should be allowed and at the end of that time a visual inspection should determine whether or not more time is needed. In making a visual inspection, look for the following:

1. The colour should be a relatively uniform brown with some white and grey flecks. Any blackness indicates incomplete combustion.
2. While the dish is still very hot, break the ash with the tips of the tongs. Any glowing embers indicate that more time is needed in the muffle. In the case of heavy sludges it is a good idea to break up the ash with the tips of the tongs and re-ignite for 15 minutes or more.

Procedure

1. Have all the dishes cleaned and weighed, and the weights noted.
2. Mix the sludge sample well and pour into the dish until it is about three-quarters full, weigh, and record the weights.
3. Place the dishes in a drying oven and leave them there overnight.
4. The next morning, remove the dishes from the oven and place in desiccator. Allow at least one hour for cooling or until no warmth can be felt if the dish is touched to the cheek.
5. Weigh accurately and record the results.
6. Place the dish in the muffle furnace and ignite.
7. When the ignition has been completed, take the dishes from the muffle and place on a clean piece of asbestos board until they cool down to about 100°C and then put in desiccator for about one hour.
Note: Never put dishes directly from the muffle into the desiccator.
8. When cool (one hour), weigh accurately and record the weight.

Calculation

- A. Tare weight of dish - 43.2548 (Weight of clean, empty dish)
- B. Weight of dish plus wet sludge 76.9037
- C. Weight of dish plus dry solids 46.3172
- D. Weight of dish plus ash 44.7870

B 76.9037	C 46.3172	C 46.3172
A <u>43.2548</u>	A <u>43.2548</u>	D <u>44.7870</u>
33.6489	3.0624	1.5302

$$\% \text{ Dry solids} = \frac{3.0624}{33.6489} \times 100 = 9.1\%$$

$$\% \text{ Volatile solids} = \frac{1.5302}{3.0624} \times 100 = 49.5\%$$

$$\% \text{ Ash} = \frac{100.0}{49.5} = 50.5\%$$

$$\text{Total Solids} = \frac{3.0624}{33.6489} \times 1000,000 = 90,800 \text{ ppm}$$

$$\text{Volatile Solids} = \frac{1.5302}{33.6489} \times 1000,000 = 45,300 \text{ ppm}$$

$$\text{Ash} = 90,800 - 45,300 = 45,500 \text{ ppm}$$

VOLATILE ACIDS

The titrating solution used in this determination is 0.0585 N Sodium Hydroxide and is prepared in the following manner:

1. Weigh accurately 2.340 grams of Sodium Hydroxide (NaOH).
2. Half fill a 1000 ml volumetric flask with distilled water which has been freshly boiled and cooled.
3. Dissolve the NaOH in the water.
4. Fill, nearly to the mark, with the previously boiled and cooled distilled water.
5. Allow it to come to room temperature.
6. Top up to the mark, shake well, transfer to a clean 1000 ml reagent bottle (glass-stoppered) and put aside until needed.

If the NaOH is supplied as a 50% W/W solution, 2.07 mls would be pipeted out and used in place of the pellets of NaOH. Otherwise, the preceding instructions apply.

Procedure

If a centrifuge is available, centrifuge enough sludge to produce 50 ml of liquid.

1. To 50 ml of centrifuged sample placed in a 500 ml boiling flask, add 150 mls of top water.
2. Add 2 ml of concentrated sulphuric acid and a few marble chips or glass beads.
3. Connect immediately to the condenser.
4. Apply heat and as soon as the liquid comes near the boiling point, cut the heat back so that a boiling action never takes place. Distill at the rate of approximately 3.0 ml/min. Collect 120 ml of distillate in a 250 ml graduated cylinder. Transfer to a 250 ml erlenmeyer flask.
Note: As you approach the end of the distillation, turn the heat back to reduce the distillation rate. This is necessary in order to prevent sulphuric acid from being carried over.
5. Test for acid carried over. To about 1 ml of distillate in a test tube, add 1-2 drops of a 1% solution of Barium Chloride. If a white precipitate is formed, discard the analyses, as sulphuric acid is present.
6. If no precipitate has formed, add a few drops of phenolphthalein indicator solution to the solution in the erlenmeyer flask and titrate to the first pink colour that remains stable for 30 seconds.

Calculation

Titre x 100 = mg/l of volatile acids expressed as Acetic acid.

As an example:

Volume of 0.0585 N - NaOH used = 3.52 mls.

Concentration of volatile acids = $3.52 \times 100 = 352$ mg/l

MILLER METHOD FOR DISSOLVED OXYGEN

REAGENTS

Alkaline Tartrate (A. T.)

Weight accurately

120 grams Sodium Hydroxide (NaOH)

345 grams Potassium Sodium Tartrate ($\text{KNaC}_4\text{H}_4\text{O}_6 \cdot 4\text{H}_2\text{O}$)

Make up to 1 litre with distilled water. If ground glass stopper is used on reagent bottle, protect stopper with stop-cock grease.

Ferrous Ammonium Sulphate (F. A. S.)

Weigh accurately

2.2 gram ferrous ammonium sulphate ($\text{FeSO}_4 (\text{NH}_4)_2 \text{SO}_4 \cdot 6\text{H}_2\text{O}$)

Measure 10 millilitres (ml) of concentrated sulphuric acid (H_2SO_4)

Dissolve the ferrous ammonium sulphate in distilled water, add 10 ml of conc. H_2SO_4 , make up to 1 litre.

Methylene Blue

1 gram of Methylene Blue

Dissolve Methylene Blue in 1 litre of distilled water.

PROCEDURE

To a glass tube large enough to hold 100 ml, such as a 100 ml Nessler tube, add 5 ml of alkaline tartrate reagent and two drops of Methylene Blue. To this add 50 ml of sample from a pipette keeping the tip below the surface of the liquid in the tube. A blue colour shows the presence of dissolved oxygen.

Titrate with Ferrous Ammonium Sulphate reagent until the blue colour disappears. While titrating, keep tip of F. A. S. pipette below surface of liquid and move pipette slowly in solution to mix contents. Do not stir or agitate vigorously as this may entrain oxygen and lead to false results.

Record ml of F. A. S. used in titration.

One (1) ml of F. A. S. is equivalent to (0.70 ml of oxygen per litre or
(1.00 parts per million of oxygen

Note: F. A. S. is perishable. Store in dark cool place and replace stock monthly.

WINKLER METHOD FOR DISSOLVED OXYGEN

It is possible, due to age, contamination etc., for the reagents to become unusable. The following procedures will determine whether or not they may be used.

1. Manganous Sulphate

Put about 5 ml of 10% potassium iodide into a test tube or a small beaker or a small erlenmeyer flask. Add, carefully, 2 -3 drops of concentrated sulphuric acid. Mix and add 1-2 mls of manganous sulphate solution. If any more than a trace of a yellow colour develops, the manganous sulphate should be discarded and a new solution prepared.

2. Alkaline Azide Iodide

Take 5 ml of this reagent and place it in a small beaker. Place the beaker in the sink and add carefully a 10% solution of sulphuric acid, stirring well, until litmus paper changes from blue to red. Then add 0.5 ml of soluble starch solution. If any blue colour appears, the alkaline azide iodide solution should be discarded and a new one prepared.

Solutions Required.

1. Manganous Sulphate

Read the label on the manganous sulphate bottle. Under formula will be one of the following:

- (a) $\text{MnSO}_4 \cdot 4\text{H}_2\text{O}$
- (b) $\text{MnSO}_4 \cdot 2\text{H}_2\text{O}$
- (c) $\text{MnSO}_4 \cdot \text{H}_2\text{O}$

An amount must be weighed out, depending on the amount of water of crystallization (the H_2O part of the formula).

For (a) use 480 grams.

For (b) use 400 grams.

For (c) use 364 grams.

Weigh the required amount. Heat some distilled water in a 1 litre or larger beaker and dissolve the manganous sulphate in it. When it is all dissolved, filter it, transfer to a 1 litre volumetric flask, cool it to room temperature and make up to the mark with distilled water. Transfer it to a 1 litre reagent bottle and put it aside.

Alkali-azide-iodide Reagent

In this reagent, the salts of potassium and sodium can be used interchangeably. It remains only to determine which is available then proceed as follows:

Dissolve 500 grams of sodium hydroxide or
Dissolve 600 mls of 50% W/W sodium hydroxide or
Dissolve 700 grams of potassium hydroxide in distilled water.

Add 135 grams of sodium iodide or
Add 150 grams of potassium iodide.

When this is all in solution transfer to a volumetric flask - 1 litre - cool to room temperature and make up to the mark with distilled water. To this one litre of solution, add 10 grams of sodium azide dissolved in 40 mls of distilled water. Mix well and transfer to a reagent bottle.

Sulphuric Acid

This is normally used in its concentrated form. 1 ml of the concentrated sulphuric acid is equivalent to approximately 3 mls of the alkaline-azide-iodide reagent.

Starch Solution

To 5.0 grams of soluble starch, add a small amount of distilled water and mix to form a thin paste. Pour into one litre of boiling distilled water, stir and allow to settle overnight. Decant the clear supernatant only, into a reagent bottle. Add 1.25 grams of salicylic acid per litre as a preservative.

Sodium Thiosulphate Stock Solution

0.1 Normal

Dissolve 24.82 grams sodium thiosulphate, formula $\text{Na}_2\text{S}_2\text{O}_5 \cdot 5\text{H}_2\text{O}$, in freshly boiled and cooled distilled water. Make up almost to the mark in a 1 litre volumetric flask, adjust to room temperature, make up to the mark, mix well and transfer to a brown glass bottle. To preserve this solution, add 1 gram of sodium hydroxide per litre or 0.8 mls of 50% W/W sodium hydroxide.

Sodium Thiosulphate 0.025N

Working or Standard Solution

Add 250 mls of 0.1N stock solution to a 1 litre volumetric flask. Fill, almost to the mark with distilled water. Bring to room temperature, make up to the mark, shake well and transfer to a brown glass bottle, preferably with a ground glass stopper.

The above two solutions must be made with all the accuracy possible.

Test Procedure

In the following a 5 or 10 ml Mohr measuring pipet will be used ,

1. Remove the stopper carefully from the D.O. bottle to avoid spilling.
2. Keeping the tip of the pipet below the surface of the liquid, add 2 mls of manganous sulphate reagent.
3. Using a second Mohr measuring pipet and again keeping the tip of the pipet below the surface of the liquid, add 2 mls of alkali-azide-iodide reagent.

NOTE: When the alkali-azide-iodide reagent is added, a heavy precipitate will form. If it does not, check the reagents and start over. If the precipitate is white there is no dissolved oxygen present, if it is amber in colour, dissolved oxygen is present.

4. Upon completion of step three, stopper the bottle taking care not to trap air. This can usually be accomplished by tilting the bottle and inserting the stopper carefully.
5. The precipitate is left to settle until it occupies one third of the bottle. (Two thirds clear liquid above the precipitate). Then remove the stopper carefully and using a fresh Mohr measuring pipet add 2 ml of concentrated sulphuric acid. This time keep the tip of the pipet above the liquid level and against the inside of the neck of the bottle, thereby allowing the acid to run down the inside.
6. Stopper the bottle and shake very well.

NOTE:

- (a) The water should take on a clear amber colour. No amber colour - no D.O. .
- (b) If there is still a small amount of precipitate left, this can usually be dissolved by adding another 2 mls of concentrated sulphuric acid. If some undissolved material remains, ignore it and proceed with the remainder of the test.

TITRATION

1. Rinse a 100 ml pipet with a small volume of the solution which has just been prepared. The pipet used should be the fast flow volumetric type.
2. Transfer 100 ml to a 250 ml erlenmeyer flask.
3. Rinse the buret with a small amount of 0.025N sodium thiosulphate. Repeat the rinsings at least three times, discarding each aliquot of rinse solution. Fill the buret with the 0.025N sodium thiosulphate and adjust it to zero.

Add the $\text{Na}_2\text{S}_2\text{O}_3$ from the buret, relatively slowly, to the erlenmeyer containing the sample. Keep the sample swirling in the flask during the titration.

When the colour of the sample changes from amber to a pale straw colour, add approximately 1/2 ml of starch solution. This will turn the liquid a blue colour. (If the blue colour does not appear, the titration has been carried too far and must be repeated.) Continue the titration, adding $\text{Na}_2\text{S}_2\text{O}_3$ drop-wise until all the blue has gone.

Read the buret and make a note of the reading.

NOTE: Do not add the starch solution too soon as a precipitate will be formed which may have an effect on the final answer.

Calculation

Number of ml of 0.025N $\text{Na}_2\text{S}_2\text{O}_3$ x 2 = mg/100 (ppm)

Example:

Volume of 0.025 N $\text{Na}_2\text{S}_2\text{O}_3$ required for titration is 2.12 ml.
The D. O. concentration is $2.12 \times 2 = 4.24$ mg/l.

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